DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE OUTRIGGER TELESCOPES PROJECT

VOLUME II

Mauna Kea Science Reserve, Island of Hawai'i

National Aeronautics and Space Administration
Office of Space Science
Washington, DC

July 2004

VOLUME II: APPENDICES

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APPENDIX A

NEPA CONSULTATIONS

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Ref. No. P-10393

February 26, 2004

Mr. Carl B. Pilcher
Keck Observatory Program Scientist
Astronomy and Physics Division
Office of Space Science
National Aeronautics and Space Administration
Headquarters
Washington, D.C. 20546-0001

Dear Mr. Pilcher:

Subject: Request for Clarification of Coastal Zone Management (CZM) Federal Consistency Applicability for the Keck Outrigger Telescopes Project at the W.M. Keck Observatory Site, Mauna Kea Science Reserve, Island of Hawaii

This responds to your request dated February 12, 2004, for confirmation that a CZM federal consistency review is not required for the proposed Keck Outrigger Telescopes Project at the W.M. Keck Observatory Site, Mauna Kea Science Reserve, Island of Hawaii. In our previous letter dated October 3, 2000, we confirmed that a CZM federal consistency review of the project by the Hawaii CZM Program was not required on the basis that: the National Aeronautics and Space Administration's (NASA) role in the project was only to provide congressionally-appropriated funding for the project; NASA was not the entity responsible for on-site construction of the project; NASA would not be the signatory of any of the required construction and/or operating permits; and NASA would not be the entity responsible for operation of the project. Because NASA's role in the project is exactly the same as previously proposed, our confirmation letter dated October 3, 2000, is still valid.

It should be noted that our October 3, 2000, confirmation that a CZM federal consistency review was not required, specifically addressed the implementation of the project itself and did not address whether a CZM federal consistency review was required for the preparation of a Federal Environmental Assessment. The preparation of a Federal Environmental Impact Statement does not necessarily require CZM federal consistency review, because a Federal agency's federal consistency obligations under the Coastal Zone Management Act are independent of those required under NEPA. This is clarified in 15 CFR 930.37 – *Consistency Determinations and National Environmental Policy Act (NEPA) Requirements.*

This confirmation is not an endorsement of the project nor does it convey approval with any other regulations administered by any other agency. Thank you for your cooperation in complying with Hawaii's CZM Program. If you have any questions, please call John Nakagawa of our CZM Program at (808) 587-2878.

Sincerely,

Mary Lou Kobayashi
Administrator

c: Planning Department, County of Hawaii

APPENDIX B
MEMORANDUM OF AGREEMENT

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MEMORANDUM OF AGREEMENT
Among
The National Aeronautics And Space Administration,
The Advisory Council On Historic Preservation,
The Hawai‘i State Historic Preservation Officer,
The University of Hawai‘i,
The California Association for Research in Astronomy, and
The California Institute of Technology,
Regarding The Outrigger Telescopes Project,
Mauna Kea, Hawai‘i

WHEREAS, the National Aeronautics and Space Administration (NASA) has determined that the placement of the four, and potentially six, Outrigger Telescopes (hereinafter referred to as the "Undertaking") adjacent to the existing Keck Telescopes at the W.M. Keck Observatory (WMKO) on the summit of Mauna Kea, will meet the purpose and need of NASA's ground-based interferometry objectives; and

WHEREAS, by signing this Memorandum of Agreement (MOA), the Signatory or Concurring Party does not necessarily signify that the party approves of the Undertaking, but rather that the provisions of the MOA are an appropriate means to mitigate effects on cultural resources in the event that the Undertaking obtains all required approvals and is implemented; and

WHEREAS, NASA has been considering other alternatives, including the No Action alternative; and

WHEREAS, NASA acknowledges that the Native Hawaiian people place spiritual and religious significance on Mauna Kea; and

WHEREAS, NASA has determined that the Undertaking will have an adverse effect on Pu‘u Hau ‘Oki, one cinder cone within the cluster of cinder cones which merge and collectively form the summit of Mauna Kea. This single landscape feature (*i.e.*, cluster of cinder cones) probably bore the name Kūkahau‘ula and is now called Pu‘u Hau ‘Oki, Pu‘u Kea, and Pu‘u Wēkiu. NASA, in consultation with the State Historic Preservation Officer (Hawai‘i SHPO), has determined that this cluster of cones satisfies the criteria to be eligible for listing as an historic property in the National Register of Historic Places (hereinafter referred to as the "National Register"); and

WHEREAS, NASA has determined that the Undertaking will have an adverse effect on the summit region of Mauna Kea, an area that NASA and the Hawai‘i SHPO agree satisfies the criteria for listing as an historic district in the National Register; and

WHEREAS, NASA recognizes that human burials exist in the summit region of Mauna Kea; and

WHEREAS, NASA has made a commitment that a Wēkiu Bug Mitigation Plan will be prepared and implemented as a part of the Undertaking and has determined that some components of the mitigation plan, including certain activities associated with habitat restoration and monitoring, could have an effect on the historic property and historic district; and

WHEREAS, NASA is aware of a complex of historic properties located to the south and west of the staging area at Hale Pōhaku, and the concern of the Hawai‘i SHPO to avoid any potential effects on two historic properties (*i.e.*, shrines) located directly south of the staging area; and

WHEREAS, NASA has consulted with the Hawai‘i SHPO and the Advisory Council on Historic Preservation (hereinafter referred to as the "Council") on ways to avoid, reduce, or mitigate these adverse effects, pursuant to 36 CFR Part 800, regulations implementing Section 106 of the National Historic Preservation Act (NHPA) (16 U.S.C. 470f), and has invited the Hawai‘i SHPO and the Council to participate in the development of this MOA and sign as Signatories; and

WHEREAS, NASA has consulted with and invited those parties who will construct, install, operate, and manage the Outrigger Telescopes—including the California Association for Research in Astronomy (CARA), which will supervise on-site construction, installation, and operation of the Outrigger Telescopes; the University of Hawai‘i (UH), which has the responsibility for the overall monitoring and management of the Mauna Kea Science Reserve; and the California Institute of Technology (Caltech), which holds the sublease for the WMKO site—to participate in the development of the terms of this MOA and sign as Signatories; and

WHEREAS, NASA is aware of the historic/cultural significance of Mauna Kea and has conducted and participated in outreach and consultation efforts in Hawai‘i to inform local communities, organizations, and the general public of its plans for the proposed construction and operation of the Outrigger Telescopes and their effects on historic properties, and has invited and considered input on potential measures that could avoid, minimize, or mitigate the effects to the historic properties on Mauna Kea; and

WHEREAS, NASA has consulted with and invited the Office of Mauna Kea Management, Mauna Kea Management Board, and Kahu Ku Mauna (hereinafter collectively referred to as OMKM) to participate in the development of this MOA; and

WHEREAS, NASA has consulted with and invited the State Office of Hawaiian Affairs (OHA), and the following Native Hawaiian organizations, the Hawai‘i Island Burial Council (hereinafter referred to as the "Burial Council"), the Royal Order of Kamehameha I, Ahahui Ku Mauna, Mauna Kea Anaina Hou, and Hui Mālama I Nā Kūpuna o Hawai‘i Nei to participate in the development of the terms of this MOA and sign this MOA as Concurring Parties; and

WHEREAS, NASA's consultations with the parties invited to be Signatories and Concurring Parties and OMKM (hereinafter collectively referred to as "Consulting Parties") indicate that off-site mitigation should focus on preservation and protection of

historic/cultural resources related to Mauna Kea and the educational needs of Native Hawaiians. As a component of the Outrigger Telescopes Project in Hawai‘i, NASA is committed to implementing effective measures to preserve and protect historic/cultural resources, expanding the knowledge of Hawaiian culture and address educational needs in the Hawaiian community; and

WHEREAS, Signatory or Concurring Party status is achieved only through signing this MOA.

NOW, **THEREFORE**, NASA, the Council, the Hawai‘i SHPO, UH, CARA, and Caltech agree that, upon NASA's decision to proceed with the Undertaking, such an Undertaking shall be implemented in accordance with the following on-site and off-site stipulations in order to take into account its effects on historic properties; and NASA shall ensure that its funding of the Undertaking is conditioned upon compliance with such stipulations.

I. CULTURAL AND ARCHAEOLOGICAL MONITORING

A. General

1. The Construction Manager, hired by CARA, the contractor(s), supervisors, and all construction workers will be provided training to become aware of the historic/cultural significance of the project site and surrounding areas of the summit as set forth in this MOA.

2. A Cultural Monitor will be provided free access for monitoring activities during excavation, other on-site construction, and telescope installation (See I.C below for qualifications and duties of the Cultural Monitor).

3. A qualified Archaeologist will be present to monitor all excavation activities (See I.D below for qualifications and duties of the Archaeologist).

4. The CARA Construction Manager will oversee the on-site professional personnel and all on-site construction and equipment installation. The CARA Construction Manager will schedule mutually agreed upon meetings with the Archaeologist, Cultural Monitor, and OMKM, to ensure that work is being carried out according to applicable terms of this MOA. The CARA Construction Manager, at the request of the Archaeologist or the Cultural Monitor or on his/her own initiative, has the authority to stop construction if the stipulations in this MOA are not being complied with.

5. The CARA Construction Manager shall encourage the Cultural Monitor and Archaeologist to work closely with one another.

6. Review of any plan hereinafter referenced shall occur within a 45-day period. When a Consulting Party provides comments to one of these plans, the party submitting the plan shall, to the extent practicable during the 45-day review period, enter into a dialogue with a commentor. NASA, at its sole discretion, may grant time extensions.

B. Monitoring of Historic Properties Affected by the Undertaking

1. Cultural -- Prior to construction, a cultural monitoring plan will be developed by the Cultural Monitor (see I.C below) in consultation with CARA. CARA shall submit the plan for review by NASA and all Consulting Parties.

2. Inadvertent Discovery of Human Remains and Archaeological Properties

a. Prior to construction, an Inadvertent Discovery of Human Remains and Archaeological Properties monitoring plan will be developed by the Archaeologist (see I.D below) in consultation with the Cultural Monitor and CARA and will comply with draft State Historic Preservation Division Rules (Titles 13-275, 13-279, and 13-280). CARA shall submit this plan for review by NASA and all Consulting Parties. Thereafter, CARA shall submit the plan to the Hawai‘i SHPO for approval.

b. The above monitoring plan (see I.B.2.a) shall include burial and notification components that comply with Hawai‘i Revised Statutes (HRS) Title 6E-43.6 (Inadvertent Discovery of Burial Sites), and Hawai‘i Administrative Rules (HAR) Title 13-300-40 (Inadvertent Discovery of Human Remains) for the burial components; and with applicable draft State Historic Preservation Division Rules (*e.g.*, Sections 13-275-12, 13-279-1 *et seq.*, and 13-280-1 *et seq.*) for the archaeological components. The burial treatment component will reflect a preference, to the extent practicable, and if confirmed to be culturally appropriate, for any human remains found to be preserved in place.

3. As a minimum, if there were to be an inadvertent discovery of human remains, the Archaeologist has the authority to halt ground-disturbing activities in the immediate area of such remains until all parties identified in the plan have been notified, and the requirements of the appropriately approved plan have been carried out.

4. As a minimum, if previously unidentified historic/archaeological properties (*e.g.*, deposits, artifacts, and stone alignments) were to be discovered during construction, the Archaeologist has the authority to halt ground disturbing activities in the immediate area of such properties until all parties identified in the plan have been notified, and the requirements of the appropriately approved plan have been carried out.

C. Cultural Monitor

1. Qualifications of the Cultural Monitor. In consultation with NASA and the other Consulting Parties, CARA shall develop criteria for and select an individual to be the project's Cultural Monitor. Any Consulting Party may submit the names of persons who they believe would be appropriate to serve as a Cultural Monitor.

   a. This individual will have knowledge or awareness of Mauna Kea's cultural landscape, and traditions, practices, beliefs, and customs associated with Mauna Kea.

   b. This individual will be able to communicate cultural values and protocols to others, both within and outside of the culture.

2. Cultural Monitor Responsibilities

   a. The Cultural Monitor will become aware of the general scope and requirements of the on-site construction and installation of the Outrigger Telescopes including, but not limited to, becoming familiar with: project boundaries, identified areas of historic/cultural sensitivity, the "Construction Best Management Practices Plan" (BMP), the construction worker responsibilities, responsibilities of the Archaeologist, and the sequence of operations to ensure that mitigation actions are implemented. The Cultural Monitor shall develop the Cultural Monitoring plan referenced in I.B above.

   b. The Cultural Monitor will provide cultural orientation to individuals who are associated with the on-site construction and installation of the Outrigger Telescopes and who will be on Mauna Kea. For safety purposes, all communication for the purpose of cultural orientation between project personnel and the Cultural Monitor will be scheduled and overseen by the CARA Construction Manager.

   c. The CARA Construction Manager will provide to the Cultural Monitor a weekly schedule of all construction activities planned for the following week. Based on that schedule, the Cultural Monitor will determine his/her need to visit the site during construction and installation as deemed necessary by him/her. For safety purposes, prior to entering the site, the Cultural Monitor will meet and confer with the CARA Construction Manager.

   d. The site and grading development drawings and the BMP for the Outrigger Telescopes project site, the staging areas, and nearby areas of the summit region will be provided to the Cultural Monitor. The Cultural Monitor shall keep a log and map notes of every visit — noting date of visit; identifying work locations; noting findings date; and reporting on potential problems, if any. All findings identified and deemed to be significant by the Cultural Monitor shall be reported to the CARA Construction Manager and OMKM; in turn, CARA shall promptly notify NASA, the Council, the

Hawai‘i SHPO, UH, Caltech, and any other Consulting Party that has requested to be notified of the Cultural Monitor's findings. The Cultural Monitor will submit a final report to the CARA Construction Manager; CARA, in turn, will provide copies to NASA, the Council, the Hawai‘i SHPO, UH, OMKM, Caltech, and any other Consulting Party that has requested the report.

e. The Cultural Monitor shall consult with the CARA Construction Manager to determine under what circumstances the Cultural Monitor should have direct authority to halt construction activities in a given area.

D. Archaeologist

1. Qualifications of the Archaeologist. The Archaeologist will be hired by CARA in consultation with the Hawai‘i SHPO and OMKM. The archaeologist serving as principal investigator for the Undertaking shall have the following professional qualifications:

a. A graduate degree in archaeology, or anthropology with specialization in archaeology, or an equivalent field;

b. At least one year of cumulative archaeological experience in Hawai‘i or the Pacific;

c. At least four months of supervised archaeological field and analytic experience in Hawai‘i;

d. At least one year of archaeological research administration or management at a supervisory level with at least four months of field experience;

e. A demonstrated ability to carry research to completion, as shown by completed theses, publications, and manuscripts; and

f. A demonstrated knowledge of historic preservation laws, rules, and guidelines.

2. Archaeologist Responsibilities

a. The Archaeologist will follow State Historic Preservation Division draft Hawaiian Administrative Rules for archaeological monitoring studies and reports (draft HAR Chapter 279). The Archaeologist will develop the Inadvertent Discovery of Human Remains and Archaeological Properties monitoring plan referenced in I.B above.

b. The Archaeologist shall familiarize him/herself with the WMKO site before construction begins.

c. The Archaeologist will become aware of the general scope and requirements for the on-site construction of the Outrigger Telescopes Project. This would include, but not be limited to, becoming familiar with: project boundaries, identified areas of historic/cultural sensitivity, the BMP, construction worker responsibilities, responsibilities of the Cultural Monitor, and the sequence of operations to ensure that mitigation actions are implemented.

d. The Archaeologist will monitor all excavation activities for on-site construction. The CARA Construction Manager will provide to the Archaeologist a weekly schedule of all construction activities planned for the following week. The Archaeologist will have access to the site and be present during all excavation activities. For safety purposes, prior to entering the site, the Archaeologist will meet and confer with the CARA Construction Manager.

e. The site and grading development drawings and the BMP for the Outrigger Telescopes project site, the staging areas, and nearby areas of the summit region will be provided to the Archaeologist. The Archaeologist shall keep a log and map notes of every visit — noting date of visit; identifying work locations; noting findings date; and reporting potential problems, if any. All findings identified and deemed by the Archaeologist to be significant shall be reported to the CARA Construction Manager, the Hawai‘i SHPO, and OMKM; in turn, CARA shall promptly notify the NASA, the Council, UH, Caltech, and the Cultural Monitor of the Archaeologist's findings. The Archaeologist will also notify the Cultural Monitor if human remains are found so that he or she can assist with notifying and consulting those individuals and organizations identified in the Inadvertent Discovery of Human Remains and Archaeological Properties monitoring plan. . The Archaeologist will submit a draft report to the CARA Construction Manager; CARA, in turn, will forward the draft report to the Hawai‘i SHPO for approval. The approved final report will be distributed by CARA, who will provide copies to NASA, the Council, UH, OMKM, Caltech, and any other Consulting Party that has requested a copy of the report.

II. ON-SITE PRE-CONSTRUCTION, CONSTRUCTION, AND INSTALLATION

A. Grading and Site Development Review

1. Proposed grading and site development drawings will be provided to all the Consulting Parties for a 45-calendar day review and comment period to ensure that every reasonable effort has been made to reduce the adverse effects on Pu‘u Hau ‘Oki and on the summit region of Mauna Kea by minimizing disturbance from the on-site construction and installation of the Outrigger Telescopes.

2. The goal of the grading and site development planning will be to minimize alteration of the cinder cone as it presently exists, maintain the general shape and form of the cinder cone as it presently exists, and to stabilize the cinder cone in the on-site construction and installation areas.

B. Construction Worker Training

1. As part of an orientation process to ensure work is carried out in as sensitive and respectful a manner as possible, the CARA Construction Manager, the contractor(s), supervisors, and all construction workers will be required to view a specially scripted training videotape reviewing the historic and sacred qualities of Mauna Kea.

2. This training videotape will be prepared by CARA in consultation with the Hawai‘i SHPO and OMKM. This training videotape will include a presentation on the history of Mauna Kea and its significance to Native Hawaiians, and an overview of what to do if human remains or archaeological properties are found. CARA shall provide the Consulting Parties an opportunity early in the videotape development process to provide ideas on subject matter that should be discussed and highlighted CARA shall afford the Consulting Parties an opportunity to review the draft script and preview the videotape before the videotape is produced in final form. Should disagreements arise, CARA will enter into consultation to resolve the disagreements. The time for such script review, videotape preview, and consultations shall cumulatively not exceed 45 days, unless CARA, at its sole discretion, agrees to a longer cumulative period.

3. The videotape or related orientation will also advise the workers of the potential that CARA will demand their removal from this Undertaking if they fail to comply with the conditions imposed by the Construction Best Management Practices Plan (see II.C below).

4. The CARA Construction Manager, contractor (s), supervisors, and construction workers will also be briefed by the Archaeologist and Cultural Monitor on Native Hawaiian objects, artifacts, and remains, and what to do if such materials are found during construction activities.

C. Construction Best Management Practices Plan

1. In order to implement a series of precautions and procedures to be undertaken to avoid or minimize adverse effects and prevent or reduce adverse impacts to the cinder cone and inner crater slope during on-site construction and installation, the CARA Construction Manager and the on-site construction and installation contractor(s) will prepare a “Construction Best Management Practices Plan” (BMP) in consultation and coordination with OMKM and UH. The BMP will be finalized prior to the start of construction. This BMP will reference this MOA and include it as an appendix.

2. Prior to the start of construction, CARA will submit the draft BMP to the other Consulting Parties for review. Copies of all comments received will be provided to NASA. CARA will take those comments into account before its final approval of the BMP and prior to mobilization. CARA will take no more than 15 calendar days to conclude consultation on any issues stemming from the comments.

3. On-site construction and installation activities related to the Outrigger Telescopes — from delivery of materials and equipment to the WMKO site or one of the two construction staging areas, excavation and removal of excess cinder to the summit stockpile area through assembly of the domes and telescopes to clean up of the staging, stockpile and WMKO site — will be managed in accordance with the BMP. The CARA Construction Manager will be responsible for following the BMP.

4. To address the effects on historic properties, the BMP will include, but not necessarily be limited to, the following items:

a. The process to be followed if there were to be an inadvertent discovery of human remains or archaeological properties (see I.B above).

b. Site characterization, including the locations of all construction and laydown/stockpile areas on the site, and temporary on-site fill material stockpiles.

c. The sequence of construction activities will be designed to minimize potential adverse effects on historic properties and to allow efficient scheduling of appropriate monitoring times.

d. The specific methods needed to protect the attributes of the historic properties within the project site, staging areas, and within the immediate vicinity of the project area will include, but are not limited to:

(1) Installing a temporary silt fence along the crater rim to facilitate on-site containment of all material, including cinder, so that no such material will spill over the slope. A silt fence will be used whenever excavation occurs within six feet of the slope.

(2) Transferring all excavated material, to the extent not necessary for backfill or Wēkiu bug habitat restoration, to other locations accessible from the established roads on the summit of Mauna Kea. These locations will be identified after consultation with the Hawai‘i SHPO and OMKM prior to the start of construction.

(3) Following all applicable County of Hawai‘i and State Department of Health (DOH) regulations concerning dust control which include, but are not limited to, suspending all dust-generating activities, securing

equipment and materials during high winds and storms, minimizing dust by spraying with water or other environmentally-acceptable soil stabilizers whenever necessary, and, if needed, covering excavated material with a tarp which is anchored down.

(4) Ensuring adherence to effective drainage and erosion control as provided for in the BMP.

(5) Ensuring that precautions are adopted to prevent potential adverse effects on the historic properties arising from use of the staging areas near the summit of Mauna Kea and at Hale Pōhaku.

(6) Providing the process and identifying the project personnel responsible for reporting the inadvertent discovery of human remains or archaeological properties pursuant to the monitoring plans referenced in I.B.

(7) Providing an organization chart that identifies project personnel with the responsibility for maintaining the integrity of the historic properties and the historic district with respect to the following:

(a) controlling all trash and construction material stored on-site so that it does not blow or fall onto surrounding areas of the summit;

(b) recovering trash and construction material which, despite best efforts, blows or falls onto surrounding areas of the summit;

(c) ensuring that all outdoor trash containers will be secured to the ground and have secured lids and plastic liners;

(d) removing all trash, construction debris, and waste material on a regular basis (weekly during construction);

(e) removing all construction equipment and excess materials in a timely manner after construction is completed;

(f) ensuring that a magnetic device is driven over roadways to remove nails and other metallic debris; and

(g) ensuring daily proper disposal of all perishable waste products.

e. To reduce the visual impact on the cinder cone and the historic district, all structures or portions thereof will be of colors designed to blend in with the surrounding terrain; provided, however, that such colors would not adversely affect the operation and scientific capability of the Outrigger Telescopes. CARA will afford the Consulting Parties an opportunity to review and comment on the colors to be used.

f. Characteristics of any discharge of a pollutant into the environment associated with the construction activity (including solid waste, sanitary waste, oily waste, or toxic/hazardous waste, if any) will be identified as soon as it is practicable. Proposed control measures and/or treatment methods for any unplanned or accidental discharge of pollutants associated with construction activity will be developed by the contractor(s) and managed in accordance with the BMP.

g. Noise associated with construction will be minimized through the use of equipment with proper noise muffling devices. Idling of equipment when not in use will be kept to a minimum. The contractor(s) must comply with Hawai'i DOH rules (HAR, Chapter 46, Community Noise Control).

D. Wēkiu Bug Mitigation

Because Wēkiu bug habitat restoration and monitoring may affect the historic/cultural resources of the project site and surrounding areas, and only for this reason, they are mentioned in this MOA. Any activities related to the Wēkiu bug itself will be covered in the separate Wēkiu Bug Mitigation Plan. Prior to implementation of the Undertaking and finalization of the Wēkiu Bug Mitigation Plan, CARA will consult with the Hawai'i SHPO to ensure that the plan contains appropriate provisions that will avoid or minimize, to the extent practicable, any potential adverse effects on the historic property and historic district. These shall include, but not necessarily be limited to, installing permanent signs identifying Wēkiu bug habitat, preventing the dispersal of debris, screening and washing cinder for habitat restoration, placement of the restoration material, and erosion control.

E. Cultural Interpretation

During the construction and installation of the Outrigger Telescopes, OMKM, in consultation with the Hawai'i SHPO, will develop and provide interpretive materials concerning the cultural significance of Mauna Kea. The Consulting Parties will be afforded an opportunity to review and comment on the interpretive materials during their development.

F. On-Site Compliance with Conditions

1. CARA shall ensure that the plans and mitigation measures reflected in this MOA for adverse effects on historic properties, including, visual impacts, erosion control, permit requirements and conditions, and monitoring commitments are incorporated into the contract(s) with its contractors and subcontractors; and that such contract(s) include a provision that CARA's Construction Manager has the authority to enforce such requirements or conditions and, if infractions occur, to order work to stop until the contractor/subcontractor is in compliance.

2. CARA shall make provisions for the Consulting Parties to monitor and review the work during on-site construction and installation activities. However, for

safety purposes, all construction site visits must be coordinated through the CARA Construction Manager's office. If it appears that the terms of this MOA are not being followed, Consulting Parties are encouraged to notify NASA, CARA, and the Hawai'i SHPO.

3. Before excavation begins, CARA and NASA will provide points of contact to the Consulting Parties, along with a copy of the final executed Memorandum of Agreement.

III. OFF-SITE MITIGATION MEASURES

Preservation and Protection of Historic/Cultural Resources and Educational Mitigation Measures

1. NASA, in consultation with OMKM, will fund, out of funds for the Outrigger Telescopes Project, an initiative that deals with preservation and protection of historic/cultural resources on Mauna Kea and educational needs of Hawaiians as a mitigation component of the Outrigger Telescopes Project. Funding such an initiative, however, is conditioned on the approval of the Outrigger Telescope's being placed at the WMKO site on the summit of Mauna Kea, Hawai'i. This initiative will be sensitive to Native Hawaiian culture, history, and institutions.

2. The necessary first step is the formation of a local citizens' working group. NASA and OMKM, in consultation with the other Consulting Parties, will ensure the formation of this working group. The working group members will serve on a volunteer basis. OMKM will coordinate and manage the activities of this working group and provide administrative services.

3. Once this working group is formed, its task will be to inform NASA as to what types of opportunities or goals will best benefit Hawaiians, including Native Hawaiians. The working group will be asked to prioritize their proposals. The working group will have one year after it is formed to develop its recommendations, but is encouraged to submit the proposals sooner, if possible.

4. Funding will be subject to the availability of appropriated funds in accordance with Federal law (*e.g.*, the Anti-Deficiency Act). Such funds will be allocated to the proposals as prioritized by the working group until available funds are exhausted.

IV. OPERATIONS

CARA will ensure that all persons involved with the operations of the Outrigger Telescopes shall be required, within a thirty day period of commencing their job, to view as part of worker orientation the training videotape which addresses the cultural significance of Mauna Kea to Native Hawaiians. CARA will report to OMKM quarterly on the status of worker compliance with the viewing of the training videotape.

V. ADMINISTRATIVE STIPULATIONS

A. Dispute Resolution

1. Should any Signatory or Concurring Party object at any time to the manner in which the terms of this MOA are implemented, NASA shall consult with the objecting party(ies) to resolve the objection. NASA shall have no more than 45 days to resolve the objection. If resolution is reached, the terms of this MOA shall be carried out in accordance with such resolution. If resolution is not reached through such consultation, NASA shall forward all documentation relevant to the objection to the Council, including its proposed response to the objection, and request the Council's comments in accordance with 36 CFR 800.2(b)(2). Any comments provided by the Council, and all comments from the Signatory or Concurring Party regarding the objection, shall be taken into account by NASA in reaching its final decision regarding the objection. NASA will promptly provide all Signatory and Concurring Parties with a copy of its final decision regarding resolution of the dispute. After reviewing NASA's decision, the Council or the Hawai'i SHPO, if in disagreement with the decision, may proceed under the provisions of V.B.2 below.

2. NASA's responsibility to carry out all actions under this MOA that are not the subject of the dispute will remain unchanged. Actions subject to dispute under paragraph 1 above shall be carried out in accordance with NASA's final decision.

B. Amendment and Termination

1. If any Signatory believes that the MOA should be amended, that Signatory may propose amendments to the other Signatories and Concurring Parties, whereupon all Signatories and Concurring Parties will consult to consider amendments pursuant to 36 CFR 800.6(c)(7) and 800.6(c)(8).

2. If NASA determines that it cannot implement the terms of this MOA, or if the Council or Hawai'i SHPO determines that the MOA is not being properly implemented, any of these three Signatories may propose that the MOA be terminated. The Signatory proposing termination shall so notify all of the other Signatories and Concurring Parties to the MOA, explaining the reasons for termination and affording these other Signatories and Concurring Parties at least 15 working days to consult and seek alternatives to termination. The parties shall then consult.

3. Should such consultation fail, either NASA, the Council, or the Hawai'i SHPO may terminate this MOA by so notifying the other Signatories and Concurring Parties.

4. Should this MOA be terminated, NASA shall either consult in accordance with 36 CFR 800.6 to develop and execute a new MOA or request the comments of the Council pursuant to 36 CFR 800.7.

C. Duration of this MOA

1. Unless terminated pursuant to Stipulations V.B.3/4 above, this MOA will be in effect until NASA, in consultation with the other Signatories and Concurring Parties, determines all of its terms have satisfactorily been fulfilled, or June 30, 2009, whichever is earlier.

2. Subsequent to the completion of the installation of Outrigger Telescopes 1 to 4, this MOA will be held in abeyance for on-site activities, pending determination by NASA as to whether Outrigger Telescopes 5 and 6 will be installed at the WMKO site. If NASA were to install Outrigger Telescopes 5 and 6, this MOA will remain in full force and effect for on-site activities during the period of installation. This MOA shall not apply to Outrigger Telescopes 5 and 6, if installation of those telescopes were to begin later than December 31, 2007. Should NASA decide to begin on-site installation of Outrigger Telescopes 5 and 6 after December 31, 2007, their installation will be considered a new Undertaking, and NASA will reinitiate the Section 106 process with the Hawai‘i SHPO and the Council.

3. Upon determination by NASA that all of this MOA's terms have been satisfactorily fulfilled, the MOA will terminate and have no further force or effect. NASA will promptly notify the other Signatories and Concurring Parties with written notice of its determination and of termination of this MOA.

D. Applicability of this MOA

1. This MOA applies only to the Undertaking as defined herein.

2. If, following execution of this MOA, NASA is unable or decides not to construct or install the Outrigger Telescopes, this MOA will automatically become null and void.

SIGNATORIES TO THIS MEMORANDUM OF AGREEMENT

FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION:

By: Edward J. Weiler Date: 2-22-02

Printed Name: EDWARD J. WEILER

Title: ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE

FOR THE ADVISORY COUNCIL ON HISTORIC PRESERVATION:

By: John M. Fowler Date: 3/5/02

Printed Name: JOHN M. FOWLER

Title: EXEC. DIR.

FOR THE HAWAI'I STATE HISTORIC PRESERVATION OFFICER:

By: [signature] Date: 2/28/02

Printed Name: Don Hibbard

Title: Deputy SHPO

FOR THE UNIVERSITY OF HAWAI'I:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE CALIFORNIA ASSOCIATION FOR RESEARCH IN ASTRONOMY:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

By: _____ Date: _____

Printed Name: _____

Title: _____

SIGNATORIES TO THIS MEMORANDUM OF AGREEMENT

FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE ADVISORY COUNCIL ON HISTORIC PRESERVATION:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE HAWAI'I STATE HISTORIC PRESERVATION OFFICER:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE UNIVERSITY OF HAWAI'I:

By: _____ Date: 3/5/02

for President Evan S. Dobelle

Printed Name: Walter S. Kirimitsu

Title: Senior Vice President for Legal Affairs, University General Counsel and Chief of Staff

FOR THE CALIFORNIA ASSOCIATION FOR RESEARCH IN ASTRONOMY:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

By: _____ Date: _____

Printed Name: _____

Title: _____

SIGNATORIES TO THIS MEMORANDUM OF AGREEMENT

FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE ADVISORY COUNCIL ON HISTORIC PRESERVATION:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE HAWAI'I STATE HISTORIC PRESERVATION OFFICER:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE UNIVERSITY OF HAWAI'I:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE CALIFORNIA ASSOCIATION FOR RESEARCH IN ASTRONOMY:

By: Frederic H. Chaffee Date: 03/01/02

Printed Name: Frederic H. Chaffee

Title: Director, W.M. Keck Observatory

FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

By: _____ Date: _____

Printed Name: _____

Title: _____

SIGNATORIES TO THIS MEMORANDUM OF AGREEMENT

FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE ADVISORY COUNCIL ON HISTORIC PRESERVATION:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE HAWAI'I STATE HISTORIC PRESERVATION OFFICER:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE UNIVERSITY OF HAWAI'I:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE CALIFORNIA ASSOCIATION FOR RESEARCH IN ASTRONOMY:

By: _____ Date: _____

Printed Name: _____

Title: _____

FOR THE CALIFORNIA INSTITUTE OF TECHNOLOGY

By William A. Jenkins Date: 3/4/02

Printed Name: William A. Jenkins

Title: Executive Vice President

PARTY CONCURRING ON THIS AGREEMENT

FOR THE AHAHUI KU MAUNA:

By: Edward Stevens Date: March 21, 2002

Printed Name: EDWARD STEVENS

Title: SPOKESPERSON

NOTE: WE SIGN THIS MOA WITH THE UNDERSTANDING THAT IT IS NOT AN ENDORSEMENT OF THE PROPOSED KECK OUTRIGGER PROJECT. IN PRINCIPLE, WE OBJECT TO ANY PARALLELING ACTIVITY IN PROGRESS SUCH AS THE STATE OF HAWAII CONSERVATION DISTRICT USE APPLICATION, AND THIS MOA AS PREMATURE IN THE PROCESS OF FIRST OBTAINING PROJECT APPROVAL FOR THIS UNDERTAKING.

Edward Stevens

PARTY CONCURRING ON THIS AGREEMENT

FOR THE HAWAIʻI ISLAND BURIAL COUNCIL:

By: **_____** ***Date:*** **_____**

Printed Name: _____

Title: _____

PARTY CONCURRING ON THIS AGREEMENT

FOR HUI MĀLAMA I NĀ KŪPUNA O HAWAIʻI NEI:

By: _____ Date: _____

Printed Name: _____

Title: _____

PARTY CONCURRING ON THIS AGREEMENT

FOR THE MAUNA KEA ANAINA HOU:

By: _____ Date: _____

Printed Name: _____

Title: _____

PARTY CONCURRING ON THIS AGREEMENT

FOR THE OFFICE OF HAWAIIAN AFFAIRS:

By: _____ Date: _____

Printed Name: _____

Title: _____

PARTY CONCURRING ON THIS AGREEMENT

FOR THE OFFICE OF MAUNA KEA MANAGEMENT:

By: L.T. [signature] Date: 3/8/02

Printed Name: LYLIAM T. GORMAN

Title: DIRECTOR

PARTY CONCURRING ON THIS AGREEMENT

FOR THE ROYAL ORDER OF KAMEHAMEHA I:

By: _____ Date: _____

Printed Name: _____

Title: _____

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APPENDIX C
DRAFT BURIAL TREATEMENT PLAN

July 21, 2004

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Draft Burial Treatment Plan,
As Amended,
For the Outrigger Telescopes Project
Mauna Kea, Hāmākua District, Hawai‘i

TMK: Zone 4, Sec. 4, Plat 15

Prepared for:
National Aeronautics and Space Administration

July 21, 2004

I. introduction

At the request of the National Aeronautics and Space Administration (NASA), International Archaeological Research Institute, Inc. (IARII) has prepared a *draft* Burial Treatment Plan for the proposed Outrigger Telescopes Project at the W. M. Keck Observatory (WMKO) site. The project area lies within the Astronomy Precinct of the Mauna Kea Science Reserve on the summit of Mauna Kea on the island of Hawai‘i (Fig. 1). The proposed Outrigger Telescopes Project consists of the on-site construction , installation, and operation of four, and potentially up to six, 1.8 m diameter telescopes placed around the existing Keck Telescopes on the area of the cinder cone, Pu‘u Hau ‘Oki, also known as Pu‘u o Kukahauula for the summit cluster of cones, that was previously disturbed for construction of the two Keck Telescopes. The area of potential effect is within State Inventory of Historic Places Site 50-10-23-21438, the cluster of summit cones, and within a proposed Historic District.

Five burial or possible burial sites have been identified on the Mauna Kea summit within the Mauna Kea Science Reserve. The Reserve covers 11,288 acres leased by the University of Hawai‘i from the State of Hawai‘i. The Science Reserve is a circular area (2.5 miles in radius) centered on the Mauna Kea summit, and includes approximately those lands above the 12,000 foot elevation, except for those areas that are part of the Mauna Kea Ice Age Natural Area Reserve. The Mauna Kea summit is located in TMK: Zone 4, Sec. 4, Plat 15. Archaeological survey has located five sites identified as Sites 50-10-15-16195, 16248, 21413, 21414, and 21416 that are thought to be burial sites.

The proposed Outrigger Telescopes Project funded by NASA would be limited almost exclusively to the existing and previously disturbed footprint of the WMKO site within the Astronomy Precinct. This Burial Treatment Plan has been prepared for NASA at the request of the Office of Hawaiian Affairs in order to address long-term management goals associated with cumulative impacts conforming to the Environmental Impact Statement (EIS) process for this specific project. The proposed Outrigger Telescopes Project at WMKO will impact no recorded burial sites, and no inadvertent discovery is expected because of previous impact to the area. This Burial Treatment Plan is responsive to the provisions of the National Environmental Policy Act. However, since the region of influence for this proposed project includes all of the Mauna Kea Science Reserve, this Burial Treatment Plan has been prepared to consider any foreseeable impacts from the construction of the Outrigger Telescopes Project, indirect as well as direct.

The purpose of the Burial Treatment Plan is to ensure that known burials in the proposed project area are identified and protected, and that any burials inadvertently discovered during construction or maintenance activities are preserved in place or reburied on the project site in specially prepared reburial areas, depending on the situation and in consultation with lineal and cultural descendants. This Burial Treatment Plan facilitates the proper treatment of human burial remains in accordance with applicable sections of Chapter

6E-43 – Historic Preservation Law (Haw. Rev. St.; as amended), and the current administrative rules for the treatment of burial sites and human remains that were formally approved and adopted by the State of Hawai‘i in September 1996 (DLNR 1996). The Burial Treatment Plan provides the Hawai‘i Island Burial Council (HIBC) with the relevant information called for in Section 13-300-33, “Request for council determination to preserve or relocate Native Hawaiian burial sites.”

This Burial Treatment Plan provides a background on the archaeological and cultural history of Mauna Kea and its significance; a discussion of the known burial sites; a discussion of the search for lineal and cultural descendants; a proposed treatment plan for known as well as inadvertent burials; and guidelines for implementation of the proposed Burial Treatment Plan.

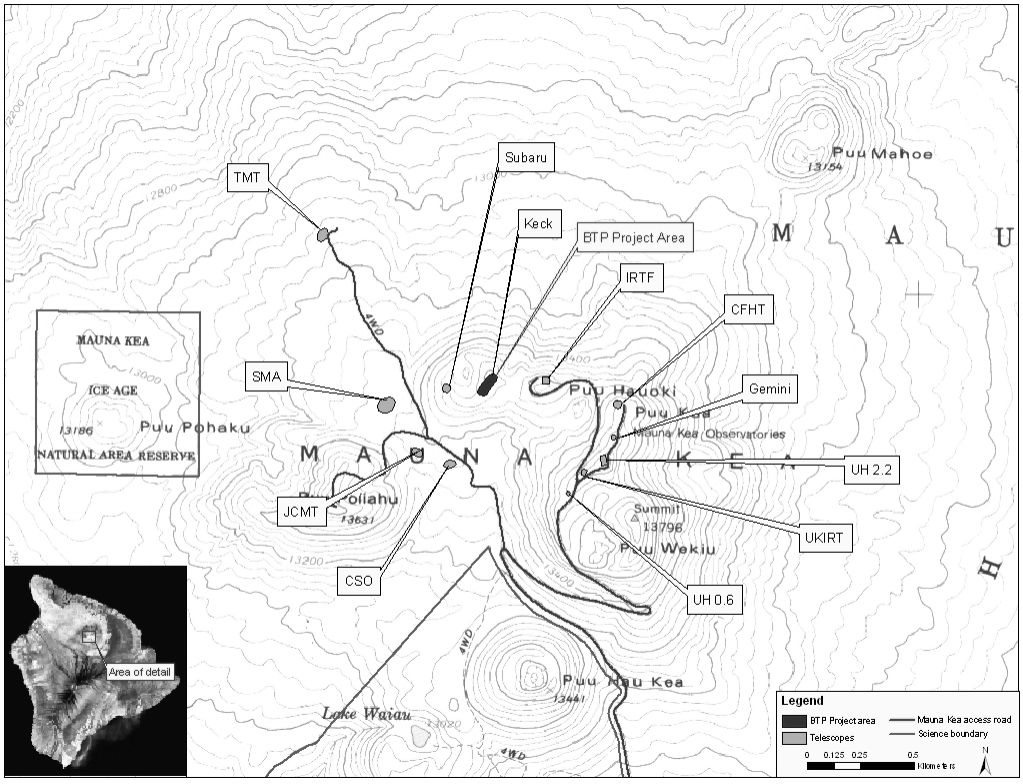

Figure 1: Location of proposed Outrigger Telescopes Project, Mauna Kea, island of Hawai‘i.

II. Background

This background summarizes what is known of the prehistory and history of Mauna Kea from the time of initial Hawaiian settlement of the island of Hawai‘i to the recent development of observatories on the summit. It updates and adds to the documentary information provided by Kepa Maly’s (1998) archival study of Ka‘ohe and Humu‘ula

ahupua'a, in Hamakua and Hilo Districts (see definitions in the section on Hawaiian Traditions below), on Hawai'i Island. These two land units include most of the lands on Mauna Kea. Mauna Kea Science Reserve and Hale Pohaku are both located in Ka'ohe *ahupua'a*, following the *ahupua'a* boundaries formalized by the Boundary Commission (e.g., Baldwin 1891); U.S. Geological Survey (1982) plots both in Hamakua District.

The documentary historical study relies mainly on secondary sources – sources where original information has already been compiled. The main sources used include Maly (1998), McEldowney (1982), and Tomonari-Tuggle (1996). Other sources are cited where used. The archival collections searched by Maly and McEldowney for their studies include those at the following repositories: the State Survey Department, the Archives of the State of Hawai'i, the Bishop Museum Archives, libraries including those at Bishop Museum and the University of Hawai'i, and Mo'okini Library. One primary source added here is a collection of papers now available at the Bishop Museum Archives in Honolulu: 45 boxes of papers left by Leicester Winthrop Bryan, who served as Territorial Forestry Office for the Island of Hawai'i from 1922 to 1949, and as Territorial Forester until 1961 (Bryan 1921-1984). Materials from Boxes 2, 7, and 14, and portions of Boxes 16, 32, and 37 have been examined.

The primary sources for the archaeological information are a number of studies by Patrick McCoy, both original research (McCoy 1977a and b, 1978, 1981, 1982a and b, 1984, 1985, 1986, 1990, 1991) and compilations of work completed in both the quarry and the summit region (especially, McCoy 1999).

general

Mauna Kea, the white mountain, or the Mountain of Wakea, is one of the most prominent features of the Hawaiian Islands, rising 4,205 meters above sea level (m asl; 13,796 feet asl). From its base on the floor of the Pacific Ocean, it is one of the highest mountains on earth. During the winter months the summit of Mauna Kea is often blanketed in snow, hence the popular translation "white mountain." In native Hawaiian traditions, however, "Kea" is also the abbreviated form of Wakea, the great sky god who, together with Papa, the earth mother, and other gods and forces, created the Hawaiian Islands. The summit is the meeting point of Wakea and Papa. In this cultural context, the summit of Mauna Kea is the domain of the gods.

These beliefs about Mauna Kea make it a highly significant and sacred place to the Hawaiian people. Mauna Kea figures centrally in Hawaiian cosmology, or and *mo'olele* (traditions, legends or stories), *mele* (song), or *`oli* (chants). According to Hawaiian beliefs, Mauna Kea is the home of a number of ancient chiefs and chiefesses who are regarded as deities. Prominent among these are Kakahau'ula, the pink-tinted snow god, Poli'ahu, goddess of the snows of Mauna Kea, and Lilinoe, her sister, the goddess of mists.

The mountain is divided into zones or levels based on altitude, physical features, and vegetation. The highest level, that of the cones of the summit, is a very sacred area reserved for the realm of deities and high chiefs and priests, while the second level, still above the tree line, is also a very special zone, reserved for use by the *ali'i* and *kahuna* (priests and masters

of arts and crafts). Lower zones on the mountain, where *mamane* and other trees grew, were for use by others, such as forest spirits and commoners (Maly 1998:7; Kanahele and Kanahele 1997:14).

This background study looks at the history of the mountain as it is known from Native Hawaiian oral tradition, from the archaeological record, and from historical accounts, documents, and maps. The first part focuses on traditional Hawaiian beliefs and oral history about Mauna Kea as recorded by native and foreign writers soon after Contact (usually defined as1778, when Captain James Cook's ships reached the Hawaiian Islands). The second part summarizes what is known about pre-Contact Hawaiian use of the mountain from archaeological studies. The third part is a review of the nineteenth and early twentieth century history of the mountain, of the consequences of Contact, as known from both documentary and archaeological sources. The fourth part briefly summarizes recent developments on the mountain.

Documentary Evidence: Hawaiian Traditions of Mauna Kea

Early historical accounts record information concerning traditional Native Hawaiian beliefs and oral history about Mauna Kea and traditional practices and land uses on the mountain. These records, although actually transcribed after Contact , focus on earlier times and traditions. The information comes from both Hawaiian and foreign sources; some of the most detailed includes family traditions remembered by 19th-century Hawaiian Boundary Commission interviewees (Maly 1998). Archaeological information, which has been provided by several studies conducted on the mountain during the 20th century, is considered in the next section.

Traditional Land Units

The Hawaiian term used by Kanahele and Kanahele (1997) for "district" (as, Hamakua, where the Science Reserve is located), is "*ʻapana,*" which is a traditional vertical land section (also, *moku o loko*, *ʻōkana*; Maly 1998; (Pukui and Elbert 1986). It is also a political division, because it is one of the land units that organized the Hawaiian chiefdom/state. As mentioned, the Mauna Kea Science Reserve and Hale Pohaku are both located in Kaʻohe *ahupuaʻa* -- a very large, inland, vertical land division within Hamakua District. Kaʻohe includes the summit lands, most lands on the upper slopes, and saddle lands between Mauna Kea and Mauna Loa. Humuʻula, the other *ahupuaʻa* researched by Maly (1998), is south of Kaʻohe, covering lands on the lower slopes and the Hilo side of Mauna Kea, continuing beside Kaʻohe to the summit of Mauna Loa.

In addition to the vertical land division of the landscape, Hawaiʻi's lands were traditionally defined horizontally, as environmental and cultural zones, *wao*, defined largely by vegetation. *Ke kuahiwi* and *ke kualono* are, respectively, the very sacred summit and the near-summit lands where few trees grow; both are very special zones on Mauna Kea. In all, 23 land zones are listed for the islands by Maly (1998:7-8). Kanahele and Kanahele ((1997:13-15), considering Mauna Kea specifically, list six zones. Downslope, below the summit zones of *ke kuahiwi* and *ke kualono* (spellings here follow Maly), are four less sacred

zones: *ka wao ma‘u kele* (below *ke kualono*; a wet area of large *koa*, *‘ohi‘a*, lobelia, and *mamane* [botanical names and English translations provided below, in section concerning pre-Contact land uses]); *ka waoakua* (an area of more varied forest); *ka waokanaka* (the lowest forested area, the one most used as a cultural resource); and *ke kula* (the upland grassy plains). A seventh horizontal land unit, the ocean edge, is listed by Maly as *ka po‘ina nalu* and by Kanahele and Kanahele as *ke kahakai*. Although the shoreline is beyond the physical boundaries of Mauna Kea as it is usually conceived, residents of isolated upland *ahupua‘a* like Ka‘ohe typically had wide access across the shoreline to the sea beyond the inshore fisheries (Lyons 1903; McCoy 1990:111-112, citing and discussing Lyons).

Of the six horizontal land divisions on Mauna Kea, only *ka waokanaka* and *ke kula* were used for everyday purposes by Hawaiians. The upper forests and higher lands were considered special and were visited rarely, usually by specialists; they were carefully conserved. The Mauna Kea Science Reserve is located above the 3,660-m (12,000-foot) elevation, in the summit area, in *ke kuahiwi* and possibly also *ke kualono*. Hale Pōhaku (in English, stone house; (Pukui and Elbert 1986), is located farther downslope, on the east side of the Mauna Kea Observatory Access Road, at the 2,810-m (9,220-foot) elevation, in an area that still contains remnant *māmane* trees (McCoy 1985). The upper elevation and the presence of native forest suggest that Hale Pōhaku is located within one of the special and conserved forest zones, either *ka waoakua* or *ka wao ma‘ū kele*.

Place Names from Early Hawaiian History and Legends

While Mauna Kea’s highest summit is that at Pu‘u Kūkahau‘ula (4,205 m asl; 13,796 feet asl), the mountain has many other peaks, an upland lake, and a broad upland plateau. The peaks are *pu‘u*, old volcanic cones; their traditional names reflect the great importance of Mauna Kea, the highest mountain in the islands, in Hawaiian history and legend.

Kūkahau‘ula is the traditional name for the highest peak at the summit. The name, as applied in the early maps by Baldwin (1891) and Lyons (1891), may describe only the highest peak (the “summit cone” of Mauna Kea, in Lyons 1891), the one now often called Pu‘u Wekiu or Mauna Kea peak. Alternatively, it may include all the peaks in the summit cluster, encompassing all three of the highest volcanic cones, Pu‘u Wekiu, Pu‘u Kea, and Pu‘u Hau Oki (Hibbard 1999; Maly 1998:11). Baldwin’s (1891) “*pu‘u*” may be either singular or plural. Kakahau‘ula was named for the Waimea, South Kohala, chief who became the husband of Lilinoe. Līlīnoe was an *ali‘i*, a chiefess (Pukui and Elbert 1986:413), who became the woman of the mountains, the goddess of mists. They were ancestors of Pae, who was a *kupuna* (elder) and high chief in the time of ‘Umi (ca. the 16th century) and known as an exceptional fisherman. When Līlīnoe died, she is said to have been buried on Mauna Kea; in 1828, Ka‘ahumanu visited the mountain to try to recover the bones. Pu‘u Līlīnoe is the high peak southeast of Kūkahau‘ula (Alexander 1892a; (Kamakau 1992:215, 285); Lyons 1891; Maly 1998:11, 25).

Kūkahau‘ula, the pink-tinted snow god, was also the lover of Līlīnoe’s sister Poli‘ahu. Poli‘ahu, after whom the high peak west of Pu‘u Kūkahau‘ula was named (Alexander 1892), became the goddess of the snows of Mauna Kea. She was not only the

sister of Līlīnoe but the rival of Pele, the fire goddess, who lives on Mauna Loa (Beckwith 1970:179); (McEldowney 1982:1.2-1.3).

Two other names for places on Mauna Kea with particular importance in Hawaiian history and legend are Waiau and Kaluakakoi. Lake Waiau and Puʻu Waiau are named for one of the god companions of Poliʻahu; Maly (1998:13), translating original Hawaiian records, found that the earliest available reference to the lake by the name Waiau is that made by Haleʻole in 1862-1863. Waiau is labeled that way by Alexander (1892) and Lyons (1891). Other sources, including Baldwin (1891), Wiltse (1862)), and earlier mappers, considered the lake an unnamed pond or Poliʻahu's pond.

Kaluakākoi (cave or pit for making adzes), also called Keanakakoʻi (Alexander 1892a; Lyons 1891; U.S. Geological Survey 1982), is one of the main special-purpose areas near the summit. The Mauna Kea Adze Quarry, where rock, especially fine-grained basalt, was collected for the manufacture of adzes and other tools, was first mapped (for a Western survey) by its traditional name, spelled Kaluahakai, by Wiltse (1862; also, Maly 1998:11); Wiltse mapped it on the Kaʻohe/Humuʻula *ahupuaʻa* boundary (the incorrect spelling was a transcription error; K. Maly, personal communication 2004). Alexander (1892a) and Lyons (1891) also plotted approximate locations for the quarry complex, which includes quarries, mounds, temporary habitation areas, and shrines.

Hawaiian Place Names that are not Traditional

Several places have now been assigned non-traditional Hawaiian names that do not appear in early records. As an example, Puʻu Wekiu, a name frequently used today for the highest peak (Kūkahauʻula), was reportedly named that (*wekiu* translating into English as "summit") in the 1920s by L. W. Bryan. The name Puʻu Hau Oki, which translates into English as "frosty peak", for the westernmost summit cone was also first recorded by Byran in the 1920s (Hibbard 1999, citing 1973 Bryan letter). Hale Pohaku was named by Bryan for two stone cabins he and the Civilian Conservation Corps built in 1936 and 1939 for use by visitors to the mountain (Bryan 1921-1984:Box 2.6-2.7; e.g., June 21, 1939, log entry). Hale Pohaku is now used as the University of Hawaiʻi Institute for Astronomy's Mid-Level Facility and visitors' center, as well as a staging area and construction camp.

Archival References to Pre-Contact Land Uses

As mentioned earlier, the written information relating to traditional land use on Mauna Kea actually comes from documents, especially transcribed Hawaiian oral testimonies, that were compiled in the 19th century, after Contact. The following information is summarized from McEldowney ((1982), and from information translated and annotated by Maly (1998). Among the most informative original sources used by these and other historians are the native testimonies in the five-volume Boundary Commission Book for Hawaiʻi, prepared in the 1870s to formalize land boundaries according to the Western system; and historical maps including those cited earlier (Alexander 1892)a, Baldwin 1891; Lyons 1891; Wiltse 1862). Other sources include records left by early foreign visitors, although it is

not always known whether the original source for much of this information was Hawaiian or another foreigner (1982:1.7).

Maly (1998:45-46), introducing the land-use information that is provided by the Boundary Commission testimonies, organizes the traditional land uses by zone: lower forest to upper forest, and upper forest to summit. The following summary is organized by site and land use type, with comments regarding the zones that were important for each.

Main trails and footpaths served the lower slopes and also provided access to lower and upper forest zones on the mountain, providing bird catchers and others access to resources including the forests and the adze quarry. Kamakau (1992:16) mentions the trail of Poliʻahu, which had been used by ʻUmi in the 16th century: "It was shorter to go by way of the mountain to the trail of Poliʻahu and Poliʻahu's spring [Waiau; K. Maly, review comment 2004] at the top of Mauna Kea, and then down toward Hilo. It was an ancient trail used by those of Hāmākua, Kohala, and Waimea to go to Hilo." ʻUmi's party of warriors descended via the trail to Kaūmana (above Hilo), camping on the way just above Waiʻanuenue Stream (Kamakau 1992:16-17).

Among the main trails is one that figured in a Humuʻula/Kaʻohe border dispute, probably the one mentioned in Waiki's testimony to the Boundary Commission; it passed from Lahohina (Puʻu Lahohinu, northeast of the summit), to or through Laumaia (Gulch, east of the summit), above the forest. The best-documented trails provided access to lower forest zones (e.g., *ka waokanaka*) and certain upper forested lands, from the lowlands or the Saddle (Maly 1998:52; McEldowney 1982:1.7-1.8).

Forest birds including *oʻo* (native honeycreepers, *Noho* species; Hawaii Audubon Society 1993:103) were hunted for their colorful feathers in the lower forests on the mountain. *He mau wai kōloa*, native duck ponds, were also mentioned in testimonies made to the Boundary Commission. Seabirds including especially *ʻuaʻu*, the dark-rumped petrel, and *nene* (*Pterodroma phaeopygia sandwichensis* and *Nesochen sandvicensis*; Hawaii Audubon Society 1993:10, 49) were hunted in the Saddle area, on the lower slopes (again, in *ka waokanaka*), and possibly at much higher elevations (Maly 1998:45-47; McEldowney 19821.7-1.8). Lyons (1903:25) indicates that the "owners" of Kaʻohe possessed the sole right to capture *ʻuaʻu.*

Hardwoods harvested in the forests included *koa* (*Acacia koa*) for canoe-building. The very durable wood of *māmane* (*Sophora chrysophylla*) was valued for *ʻōʻō* (spades, digging sticks) and the runners on sleds (Neal 1975:443; Pukui and Elbert 1986:236). Lyons (1903:25) indicates that the upper limit of the *māmane* forest coincided with that of Humuʻula (Hilo District). *Pili* grass (possibly mountain *pili*, either *Panicum tenuifolium* or *Trisetum glomeratum*; Wagner et al. 1990:110, 1573, 1602) was collected on lower slopes, along with bananas and *hāpuʻu* (*Cibotium*, tree fern). And *ʻōhiʻa* (*Metrosideros polymorpha*) formed extensive forests in areas below the *māmane* forest, in the saddle (as reported by Hawaiians to William Ellis in 1823) and in the Hakalau Forest on the Hilo slope (Maly 1998:38; Tomonari-Tuggle 1996:11-16). As mentioned, *ʻōhiʻa* was an important component of *ka wao maʻu kele*, the wet, uppermost forested *wao*.

Near the summit, in the highest zones, Kaluakāko‘i, the Mauna Kea Adze Quarry, was used by lithic specialists, specialists in the manufacture of stone tools, for the collection of rock, especially fine-grained basalt (hawaiite), which was worked into adzes for canoe-making and other purposes. The historical records that are most informative about use of the quarry prior to Contact (most of the available information is archaeological and covered below) include Waiki's testimony before the Boundary Commission (Maly 1998:46, 49-52,"Haiki" in McEldowney (1982:1.7)). To support his claim that the Ka‘ohe/Humu‘ula *ahupua‘a* boundary had actually passed across the summit (west of the current boundary, the location finalized by the Commission), Waiki cited Kaluakāko‘i and a cave on Poli‘ahu as landmarks along the boundary. Waiki was born ca. 1819; his father and grandfather were bird catchers and canoe-makers and had traditionally collected stone for adze-making at the quarry. His father-in-law pointed out traditional boundaries to Waiki, who assisted Wiltse ((1862) in surveying Humu‘ula. The testimony of Kahue, another informant, agreed that resources and lands in Humu‘ula included Kaluakākoi, Poli‘ahu, and also Waiau (Maly 1998:46, 49-52).

Other site types on the mountain mentioned in testimonies and other historical documents include, importantly, burial sites; other ceremonial sites, which include bird-snarers', adze-making, and other shrines, primarily uprights and *ahu* (cairns and altars); special places such as those where *mele* were sung; and *kauhale* (house compounds, each composed of a group of buildings such as eating houses, sleeping house, and cookhouse) (Maly 1998:11, 46; Pukui and Elbert 1986:135).

The burial sites listed for the Boundary Commission by Hawaiian informants are located several kilometers northeast of the summit, at slightly lower elevations. They include a site at Pu‘ukuka‘iau, likely the point mapped by Lyons (1891) as "Kuka‘iau," approximately 17 km northeast of the summit (in Kuka‘iau *ahupua‘a*); a site or sites at Keahuonaiwi, on the slope of Pu‘ukihe, 11.5 km northeast of the summit (on the boundary between Kuka‘iau and Koholalele *ahupua‘a*, as mapped by Lyons, but reportedly belonging to Ka‘ohe); a site at ‘Iolehaehae (also 11.5 km northeast of the summit); and in unspecified areas. Several 19th- and 20th-century visitors commented on the former use of the summit and the upper slopes and plateau, both in the uppermost two horizontal environmental zones, for burial (Maly 1998:46, 53, 57; (McEldowney 1982:1.8-1.9). Lyons (1891) reported a burial site at Keonenui, around the 2,896-m (9,500-foot) elevation, a short distance southeast of ‘Iolehaehae. In 1892, Alexander's party observed burials and a possible *heiau* on Pu‘u Līlīnoe, on the east side of the Humu‘ula Ranch Trail (also called the Humu‘ula-Mauna Kea Trail) to Waimea.

Alexander noted:

> …the surveyors occupied the summit of Lilinoe, a high rocky crater, a mile southeast of the central hills and a little over 13,000 feet in elevation. Here, as at other places on the plateau, ancient graves are to be found. In the olden time, it was a common practice of the natives in the surrounding region to carry up the bones of their deceased relatives to the summit plateau for burial [Alexander 1892b].

Shrines recorded in traditional Hawaiian history and legend near the summit, in the highest land zone, include, in addition to the possible *heiau* at Puʻu Līlīnoe, Pōhaku a Kāne, a sacred platform or *ahu* perched above the sacred water of Kāne; and an *ahu* or mound at Waiau, near the Humuʻula-Mauna Kea Trail (Maly 1999:15). Puʻu Kole was a *kūahu* (altar) *manu*, an altar for bird catchers, with a *kauhale*, located around 2,400 m asl, midslope, in Laupahoehoe (below Puʻuʻulaʻula, northeast of the summit). A large *ahu* was located at Mā kanaka, a *kūahu* in Ahuapoʻopuaʻa (in Humuʻula), and an *ahu* (called Keahu o Kuakini by the 1870s) in Pōhakuloa (Maly 1998:28, 30, 45-46, 48). Both of these were located in upper forest or higher lands. *Mele* (chants) were sung in gulches including Kahawai Koikapue, whose waters were shared by Kaʻohe and Humuʻula (Maly 1998:48). *Kauhale*, in addition to the one just mentioned, included upland houses in Humuʻula and other areas, as mentioned by Boundary Commission informants (Maly 1998:46-47, 49, 50, 52). Most were located in the lower or upper forest zones.

Sacred and special-purpose sites were present in several traditional zones, from the base to the summit of Mauna Kea, and in various *ahupuaʻa* around the mountain. The other land uses, such as the use of trails, quarrying, and bird-snaring, either occupied small portions of their zones or had only transitory effects on the environment (for instance, wearing a path or harming a single tree), conserving the forests and other lands where they occurred.

Archaeological Evidence for Pre-Contact Land Uses of the Mountain

Archaeological surveys of the summit region, the Mauna Kea Adze Quarry, and Hale Pōhaku have documented many archaeological sites that indicate Hawaiian visits to Mauna Kea before Contact in 1778. Excavations of workshops and shelters within the quarry have yielded especially rich information about native Hawaiian practices on the mountain.

Polynesian Settlement of the Island of Hawaiʻi

Polynesians sailing from islands to the south, in east central Polynesia, may have arrived in the Hawaiian Islands as early as 1,600 years ago and had certainly reached the islands by 1,200 years ago. The evidence for early settlement on the island of Hawaiʻi itself remains rather unclear. The earliest well-dated site is Waiʻahukini rockshelter, a site near South Point, used mainly as a fishing camp based on the large numbers of fishhooks and other fishing gear recovered. Both charcoal and shell samples from the lower cultural layer suggest occupation began between A.D. 650 and 850 (Emory and Sinoto 1969; Spriggs and Anderson 1993). On Oʻahu the picture is somewhat clearer; there is evidence from many locations on the island that show a major change in the lowland environments occurred about A.D. 850-950. These changes are clearly associated with the arrival of human colonizers of the islands and, perhaps more significantly in terms of the impact on vegetation, of the Pacific rat that came with the Polynesian voyagers (Athens et al. 2002). The early settlements were located along the coasts of the islands in locations that provided easy access to land well-suited for growing taro (*Colocasia esculenta*, an aroid with edible leaves and underground stem [corm];

the main Hawaiian staple food) and other crops. There is no archaeological evidence for use of the high inland areas during the first few centuries of settlement.

It was probably in these early years of settlement that the Hawaiian traditions and beliefs discussed above, about the highest place on the island, the summit of Mauna Kea, took form. Mauna Kea came to be regarded as sacred, the abode of the gods, a sacred place between earth and the sky, home of Wākea. However neither archaeology nor the much later documents of the post-Contact period provide evidence about the initial development of these traditions.

Early Journeys to the Mountain

Archaeological evidence suggests that Hawaiian entry into the region of the high volcanic mountains, Mauna Kea and Mauna Loa, and the Saddle between them, began in the 12th or early 13th century. The Hawaiians began using the lava tube caves and blisters along the lower slope of Mauna Loa in the Pōhakuloa portion of the Saddle for shelter about this time, based on a large series of radiocarbon dates from firepits in several of these shelters (Athens and Kaschko 1989; Reinman and Schilz 1994). Associated with these firepits are stone flakes, bird bones, and, rarely, marine shells, the remains of the materials left behind by the early expeditions. Hawaiians stayed overnight in these shelters probably while hunting the birds that inhabit the *māmane* and *naio* forests of the Saddle, and perhaps collecting stone for manufacturing tools from small dikes of basalt and volcanic glass that are found in the Pōhakuloa area (Bayman et al. 1999; Williams 2002).

During this same period and perhaps even earlier (McCoy 1999), Hawaiians began making their way up the slopes of Mauna Kea, camping in rockshelters near the summit. The goal of the earliest pilgrimages is uncertain; most likely they were made for spiritual reasons to honor the gods associated with the mountains, perhaps to make astronomical observations, perhaps in connection with navigation. Whatever the reasons, near the summit, on the south side of the mountain, they discovered large deposits of a very hard, fine-grained volcanic rock, now called hawaiite by geologists, a stone of much higher quality for stone tool-making than the dike and extruded basalts found elsewhere. Radiocarbon dates from the earliest of the campsites used by Hawaiians procuring stone at the quarry demonstrate that by A.D. 1100 to 1300, at the latest, Hawaiians were journeying to areas near the summit of the mountain.

Procurement of Stone: the Mauna Kea Adze Quarry

For the next 500 years, until the beginning of sustained Western contact (after Captain Cook's arrival), groups of Hawaiians would journey to the summit to collect stone from the treeless alpine desert on the south side of the mountain. Most quarry sites are clustered in a 4-sq-km area between 3,350 and 3,780 m (11,000 and 12,400 ft) in elevation, although some extend down to about 2,600 m (8,600 ft).

The attractiveness of the stone for the tool-makers was the result of the unusual conditions in which it formed. During several intervals during the Pleistocene, the volcano summit region was capped by glacial ice. Geological interpretation suggests that the very

dense, fine-grained hawaiite found on the upper slopes of Mauna Kea was formed as a result of a lava flow eruption beneath the ice cap, causing the magma to cool exceptionally quickly (S. C. Porter's 1987 research, cited, McCoy 1990:93). This quick-cooled lava yielded an especially fine-grained stone that could be turned into high-quality adzes, tools used traditionally to cut trees for woodworking and then to shape the wood for canoes and many other objects. One such eruption formed an escarpment of dense rock on the south side of the mountain below Lake Waiau, and this escarpment became the focus of stone procurement and working.

The scale of the enterprise was greater than any other of this type in Hawai'i. The quarry, including less intensively worked areas below the escarpment, was defined as covering 12 sq km, larger than all other known stone quarries combined. Archaeologists working at the quarry have identified over 264 workshop areas. These include areas where the stone was obtained and initially processed into blocks that could be taken elsewhere. Others are places where these blocks were further refined by percussion chipping. Some of these workshops include huge piles of waste debitage over 5 m high where the raw material was processed into "preforms" that could serve as blanks for making adzes (the most important Hawaiian tool for working wood).

When staying on the cold summit while working at the quarry, the Hawaiians protected themselves in the small rockshelters that are found on the mountain slopes. In these shelters there is evidence of the foods that the Hawaiians carried to the summit, hearths for cooking the food and for warmth, and stone flaking debitage. The entrances of many shelters were enclosed by rock walls. '*Opihi* shells may have been used as peelers for removing the corm or underground stem of the taro, which seems to have been one of the most important foods for those working at the quarry. Bird bone awls and volcanic glass flakes, used respectively to pierce and scrape wood and other soft materials, were other common tools. In one shelter an awl and flakes were found with pandanus leaves, possibly suggesting repair of mats or baskets, but it is perhaps more likely that the pandanus leaves were for use in offerings. Other perishable materials recovered in one of the shelters were a possible ti-leaf rain cape, sandal fragments, twisted cordage, and braided sennit (Allen 1981). In another shelter a silversword was found, wrapped with pieces of tapa cloth, pandanus leaf, and a wooden bottle gourd stopper with sennit cord attached. Food remains include shells of sea urchins, a barnacle, and marine mollusks including *'opihi*; and bones of fish (at least eight families represented), bird, most of which is probably dark-rumped petrel, but which also includes small numbers of native birds that are now rare or extinct (the Hawaiian rail, coot, goose, duck, and crow, and honeycreepers); and mammal (pig, dog, and Pacific rat). Cultivated plants found at these sites most commonly are taro, ti, sugar cane, and gourd; seeds and fruits of wild plants are also common. The wild plants may have been available on the slopes of the mountain; others, such as the taro, ti, sugar cane, and gourd, were grown at lower elevations and carried up to the quarry.

From the hearths used for cooking and warmth come the fragments of charcoal that are used to date by radiocarbon analysis the use of the summit. Charcoal samples from the basal layers in three rockshelters have been dated to between A.D. 1100 and 1300, indicating

that use of the quarry began within this period. The largest number of dates fall within the A.D. 1300-1650 year range, suggesting that this was a period of major use of the quarry.

An important aspect of the quarrying was the construction of shrines. As many as 45 shrines, identified as such on the basis of the presence of one or more upright stones, are found within the quarry. Most of these are directly associated with stone workshops or are above rockshelters, and their construction is therefore interpreted as relating to quarry activities. According to McCoy (1990), the surfaces of many shrines mimic workshops, with adze-manufacturing by-products scattered beneath the uprights, suggesting their use as ritual offerings. The shrines clearly reflect the close integration of spiritual beliefs and material practices in traditional Hawaiian culture.

Ritual Sites on the Mountain

In addition to the many shrines associated with the adze quarry, shrines are found in locations on the mountain where no evidence has been recovered to suggest any material resource procurement. For example, above the quarry, archaeological survey to date has revealed the presence of 93 sites within the Science Reserve; an additional 10 sites have been recorded high in the Natural Area Reserve, around Lake Waiau. Seventy-six of these are shrines, each comprised of a single upright stone or of multiple upright stones set together in a row or rows or grouped within a paved court area. Eight additional shrines are part of four adze-manufacturing workshops separate from the quarry.

The distribution of the shrines is of importance in interpreting their use and the traditional Hawaiian activities at the summit. Although *ahu* or *heiau* recorded historically (in documents) include one at the summit, the shrines recorded archaeologically in the Science Reserve are all located on the summit plateau, with none on the central summit cones or in their immediate vicinity. Most are located between 3,901 and 4,023 m (12,800 and 13,200 feet) in elevation and are concentrated most heavily on the north and northeast side of the mountain. The absence of shrines on the summit and their presence on the plateau may reflect environmental differences between the *pu‘u* and the plateau, may result from differential preservation, or may suggest that the core summit region from about 4,023 m in elevation to the highest cone was largely avoided because of its high degree of sacredness.

The concentration of sites on the north and northeast sides also could be the result of survey bias or differential preservation, as the south side of the mountain has been more intensely modified in the past century. However, the distribution might also suggest that the usual approach to the mountain was not from the Saddle but rather from north side of the mountain, Although historical accounts such as that concerning the Poli‘ahu Trail, used by ‘Umi in the 16th century, document the use of trails from other directions, as well. It seems in any case that most access to the summit was intended for high-ranking *ali‘i* from the population centers of Ka‘ohe and Hāmākua, the *ahupua‘a* and district within which the summit falls (according to the current boundaries).

In the absence of any organic remains associated with the summit shrines, it has not been possible to date directly the time of their use. Their similarity in style to the shrines in

the adze quarry complex suggests that their time of construction and use may correspond with those dated shrines. However, the use of uprights as the central focus of the shrines is similar to early *marae* (temples) common in the islands of central and eastern Polynesia, the area from which the Polynesian voyagers came to Hawai‘i. This could be an indication that the first construction of these shrines may have begun quite early after Polynesian colonization, perhaps even earlier than the use of the quarry. Later, the use of uprights as the central focus of religious structures was replaced with a new type of temple structure as the Hawaiian *heiau* developed. McCoy (1982a, 1990) suggests that the summit region shrine complex reflects a historically undocumented pattern of pilgrimage to worship the snow goddess, Poli‘ahu, and the other mountain gods and goddesses.

Based on present knowledge, it seems that there are eight cairn sites on the summit plateau, of which one has been confirmed as containing burials and four others of which are considered likely to contain burials, based on similarities in form and placement to the known burial sites. All possible burial sites are located on the rims of cinder cones, although not on any of the highest cones at the summit itself. The known burials are on Pu‘u Mākanaka, northeast of the summit, three possible burials are located on cones northwest of the summit, and one is located on Pu‘u Līlīnoe, southeast of the summit. The distribution of burial sites, like that of shrines and other sites, may reflect differential preservation or may, as suggested by the burial places remembered by historical interviewees (e.g., Maly 1998:46, 1999:18-19), reflect a traditional preference to inter burials near the summit, but not in the most sacred region at the summit itself.

Post-contact Land Uses and Environmental Change

Contact with the Western world, beginning with the arrival of Captain Cook in the islands in 1778, altered in significant ways the relationship of the native Hawaiians with Mauna Kea. These changes completely alter the patterns of use, as reflected in the archaeological record of the post-Contact period, compared with that for the period before Contact.

Factors Causing Change after Contact

A number of factors were responsible for these post-Contact changes. The effect that appears to have been felt first and very rapidly after Contact was the reduction of the demand for stone tools with the introduction of iron and the very rapid and widespread adoption of iron tools by the Hawaiians. While the use of stone tools did not disappear (iron and stone tools are found together at some early post-Contact sites), iron replaced stone for most uses, and the need for new lithic raw material disappeared. As a result quarrying activities on the Mauna Kea summit appear to have ceased very soon after Contact. As noted above there are already indications in the archaeological record of decreased use during the last century before Contact. No materials introduced after Contact are found in the sites at the Mauna Kea Adze Quarry complex, nor are there the discarded remains of any animals and plants that were introduced after Contact.

The presence of only one reference in the early historical literature to actual quarrying on Mauna Kea (by the father and grandfather of Waiki, the man mentioned earlier who was born ca.1819) also suggests that these activities ended soon after Contact. Early European visitors to Mauna Kea observed the piles of flakes and adze preforms and the shelters, but are quiet in terms of any discussion of Hawaiian stone procurement or tool manufacture (e.g., McCoy 1977a and 1978:1, citing Joseph Goodrich, who accompanied Ellis to the summit in the 1820s and was the first to document the existence of the Mauna Kea Adze Quarry). This is interpreted as suggesting the rapid demise of stone adze manufacture and thus a reduced need for the raw stone material after the introduction of iron.

Several other factors were to reduce significantly the presence of Hawaiians on the mountain after Contact. The changes in Hawaiian social organization with the introduction of foreign ideas and goods and the unification of the islands under Kamehameha I produced changes that affected the use of this area. Regalia based on Western models began to supplant the traditional ways of expressing rank, such as the wearing of feathered cloaks by the *ali'i*, reducing the demand for hunting the colorful feathered birds in the upland forests. The introduction of foreign diseases to which the Hawaiians had no developed immunity severely reduced the population. The abolition of the *kapu* system in 1819 by Kamehameha II and others (Queen Keopuolani and Queen Ka'ahumanu), and the coming of Christian missionaries beginning in the following year ended certain traditional ritual practices and meant that those who continued to practice some of the traditions did so less conspicuously. Even though old shrines may have continued in use, new shrines were probably no longer ritually erected on the mountain. Thus the near-absence of clearly traditional sites on the summit is not surprising. While the traditional practices associated with the mountain were certainly not completely abandoned, as might be thought from reading the 19th-century documents of those non-natives who traveled around or up the mountain (discussed below), they were not as prevalent as in pre-Contact times.

Introduction of Cattle and Sheep and Environmental Degradation

Widespread environmental change began on the slopes of Mauna Kea soon after the introduction of cattle in 1792-1793 by Vancouver, who brought them from California. Vancouver gave cattle to Kamehameha I, who placed a *kapu* (restriction) on them for 10 years after Contact. Cattle were allowed to roam free and their numbers multiplied; soon they were grazing over wide areas that included the slopes of the mountain (Kamakau 1992:164); Kuykendall and Day 1962:33-34). By the 1820s the hunting of wild cattle was commercialized, supplying whaling and other ships with meat. By the 1830s, tallow and hides were also exported, and cattle ranching developed in Waimea. Wild cattle soon destroyed much of the vegetation cover on slopes where they grazed, turning native forests, shrub lands, and grasslands into pasturelands covered by introduced grasses. Cattle were observed by Ellis's party on the slopes above the forested zones by 1823 and, by 1840, were plentiful near the summit, as observed by Charles Wilkes, who commented that they must have been there either to drink snow or to escape hunters, as there was no vegetation to graze. Wilkes also commented on the fleas the cattle brought; insects thrive in cattle herds.

Between 1855 and 1868, Charles de Varigny commented that *nēnē* were being hunted to extinction in the saddle area, and were being replaced for purposes of hunting by cattle, boars, and wild dogs. Wild pigs, whose arrival on Mauna Kea is not well-documented, spread invasive introduced plants, harming the forest understory and the native forest birds who had formerly fed in it. Feral pigs were still present in 1985-1986 in areas where *māmane* grew, near Hale Pōhaku (Bonk 1986). Pigs would also have fed on tree ferns, as they do elsewhere, encouraging water to pool in the stumps and inviting mosquitoes to breed. The Humu‘ula Sheep Station was established, informally in 1856 to take advantage of feral sheep already present in the saddle (Maly 1998; Staples and Cowie 2001; (Tomonari-Tuggle 1996:17-18, 38-40)).

Firewood and other lumber were harvested commercially soon after Contact, decimating *koa* forests on Mauna Kea and elsewhere. *Pulu*, a silky fiber collected from *hāpu‘u,* the tree fern, was collected for export as pillow and mattress stuffing. Sugar cane was planted extensively on lower lands, below the forests, by the mid-19th century. Sugar mills needed large amounts of firewood, further depleting the mountain forests above, and their flumes both diverted mountain water and transported forest lumber downslope (Kuykendall and Day 1962:122; (Tomonari-Tuggle 1996:18-19, citing earlier sources).

In 1892, Alexander and his party, noting the spread of grass on the slopes, commented that, if not for the scant rainfall, they would be superb grazing land. He also reported that the *māmane* forests had all but disappeared on the western side of the mountain, and that even *‘ahinahina* (silversword, *Argyroxiphium sandwicense*; Wagner et al. 1990:261), high on the slopes, had nearly vanished (Maly 1998:38-41, 57-58). Many visitors, Hawaiian and foreign, had commented on the sandy nature of the upper-slope soils and sediments on Mauna Kea; Wilkes noted that the *pu‘u* were composed of knee-deep loose sand. The stripping of tree and shrub cover would have led to increasing erosion on all slopes in the uppermost zones and those in deforested areas below, although that is not specifically noted in available 19th-century reports.

Nineteenth-Century Visits to the Mountain

Early European and American visitors reported difficulty obtaining guides to the highest areas on Mauna Kea. Although the reason was almost certainly the sacredness and special status of the mountain, especially the uppermost zones, in Hawaiian culture, some visitors concluded that the interior area was a virtually unknown wilderness (Maly 1998:38, quoting William Ellis in 1823). Foreign visitors apparently began to climb the mountain soon after Contact, as Joseph Goodrich, accompanying Ellis in 1823, found a rock cairn at the summit that he believed had been left by an even earlier visitor. Goodrich also mentioned foot paths through the large sandy region downslope.

Visits to the mountain increased in both frequency and in the numbers of people involved throughout the 19th century. In 1830, Kauikeaouli, Kamehameha III, visited the mountain on horseback, along with Hiram Bingham. In 1840, the Wilkes party (the U.S. Exploring Expedition party) documented Lake Waiau. In 1862, Wiltse and others began surveying boundaries on the mountain for the Boundary Commission. Isabella Bird, who

traveled through many tropical lands, visited Mauna Kea in 1873. In 1882, J. S. Emerson, surveying other areas on the island, sketched Mauna Kea. In 1883, Queen Emma traveled over the mountain to Waimea; a pillar or cairn built to commemorate her visit was observed in 1892 by Alexander (1892b). In 1889 and 1891, E. D. Baldwin mapped the summit and near-summit areas, preparing his 1891 map (Baldwin 1891; Maly 1998).

Other changes during the 19th century included the building of cairns to commemorate visits. Two have been mentioned: the one built for Queen Emma's visit, and the one at the summit observed much earlier, in 1823, by Goodrich, with Ellis's party. The Wilkes party erected a cairn in 1840. In 1891, Baldwin's party erected a cairn on the summit (Maly 1998); and, the following year, Alexander (1892b) built "a solid pier of masonry," with a flat rock for a pendulum apparatus. Three cairns are the only archaeological sites on the summit plateau that have been recorded during recent surveys (McCoy 1999).

Most of these groups traveled on horses, who, along with the cattle, no doubt obliterated many small earlier trails. Larger, wider roads built in the mid-19th century included the Judd Road, started in 1849 (south of Kailua, Kona) but completed only to a point just short of the 16th milepost; construction ceased in 1859. Built by prisoners, it was to cross the saddle all the way to Hilo. The mileposts were of *ʻōhiʻa* wood. The road, at its 14-mile point, passed very near Ahu o ʻUmi, a *heiau* said to have built by ʻUmi in the 16th century to celebrate a victory (Bryan 1921-1984:Box 7.10 [article and photographs originally published in the *Hilo Tribune Herald*, April 17, 1960]).

Late Nineteenth-Century Ranching

The Saddle and the lower slopes of the mountain witnessed the development of two large ranches in the late 1800s. These competed for the rights to raise cattle and sheep and hunt feral animals in the region. John Parker II held a lease to lands in Kaʻohe from sometime before 1876. The Waimea Grazing and Agricultural Company leased Humuʻula to the east from Kamehameha III around 1860 and raised sheep and also killed wild cattle for their hides. Their one sheep station along the current Mauna Kea Observatory Access Road, just above today's Saddle Road, was a remote and rather lonely place. A wagon road was built from Humuʻula to Waimea to transport wool to the harbor at Kawaihae. By 1885 the Humuʻula lease was held by the Humuʻula Sheep Station Company, which in that year obtained the lease for the east side of Kaʻohe, while Parker Ranch continued to lease the west side. The company hired immigrant Japanese stonemasons to build stone walls around their grazing lands in the 1890s; portions of these are still standing. After 1900 Parker Ranch expanded and took over control of the Humuʻula Sheep Station Company, and most of the lands in the Saddle became a part of Parker Ranch (Langlas et al. 1997; Peterson 2003).

In the late 19th century, the main trails on Mauna Kea increasingly merged with those serving the Humuʻula Sheep Station and Umikoa Ranch wagon trails, and additional roads began to appear. Among the better-known today are the Humuʻula-Mauna Kea Trail, on the Hilo side of the mountain, and the network of trails that join to become the Kahinahina Jeep Trail, which serves the upper slopes and circles the mountain (e.g., Bier 1988; (McEldowney

1982:1.12-1.13). All these roads provided increasingly easy access to all the traditional *wao* (environmental zones), and to the summit.

Early Twentieth Century

The 20th century brought additional, and rapid, change, especially with the planting by foresters of imported trees and other plants; and with road construction and the establishment of the observatories on Mauna Kea. Sheep were still numerous on the slopes in the 1930s -- some 40,000 around the mountain. One of L. W. Bryan's tasks as head of the Civilian Conservation Corps (CCC) was to build a sheep-proof fence around the summit of the mountain, to protect the remaining *māmane* forest and also the silversword, which he commented in a 1974 letter had been devastated by wild sheep. *Māmane* continued to be endangered in the 1970s, the cause debated but possibly involving all of the cited causes: sheep, cattle, goats, fires, lumbering, and the growth of grasses that compete for the soil moisture needed for *māmane* seed germination (Bryan 1921-1984:Boxes 2.5 [inspection on 12/27/1935], 7.1 [1974 letter], 7.3 [newspaper articles]; (Tomonari-Tuggle 1996:18).

The CCC improved one of the main early roads, the Keanakolu Road, on the east side of the mountain, so that automobiles could now circumnavigate it. Bryan, as Forestry Officer and later Territorial Forester, eventually assumed the direction of the reforestation of denuded lands that had been initiated by Harold L. Lyon and the Hawaiian Sugar Planters Association in 1918, planting large numbers of trees – most of them introduced species – to control erosion (Bryan 1921-1984:Box 7.5 [brief history of Hawaiian forestry]; (Tomonari-Tuggle 1996:42-44)). The reforestation undoubtedly prevented much soil erosion, but also resulted in the additional isolation of the remaining patches of native forest.

Bryan and the CCC built the two stone cabins at Hale Pōhaku in 1936 and 1939, for use by visitors (Bryan 1921-1984:Box 2.6-2.7 [e.g., June 21, 1939, log entry regarding laying out second cabin]; (Pukui and Elbert 1986:38-39). Both have been preserved and remain in use today.

Recent Developments: Observatories on the Mountain

The road improvements undertaken by the CCC were the first steps toward making the mountain more accessible and opening up new opportunities. With the coming of World War II, the U.S. Army took control of a large area in the western portion of the Saddle to use for training. This area was to remain in military hands after the war, developing into the Pōhakuloa Training Area, closing a large portion of the Saddle to public or private commercial use. However, the use of the area for training and the concern with providing an access route in case of Japanese invasion led to the construction of a graded, all-weather road through the Saddle by the CCC and U.S. Army Corps of Engineers in 1943. After the war, the Saddle Road, linking Hilo with Waimea, was paved, further easing access to Mauna Kea [Langlas et al. 1997:26].

In the early 1960s, interest grew in establishing an observatory on the summit. A paved road already existed from the Saddle Road at the base of the mountain to Hale Pōhaku.

In 1964, a road was graded and graveled from Hale Pōhaku to the summit (Pickles 2003). The construction of this road, which became the Mauna Kea Observatory Access Road, opened up access to the summit and initiated intensive modification of the summit region.

Bishop (2003:27) provides a list of the main telescopes built at the observatories from 1968 through the present, with the years of their installation, beginning with the Air Force 0.6-m optical telescope south of the summit ridge in 1968. Its installation was quickly followed by a several other telescopes in the following five years, and then, in 1979, three telescopes. Following the completion in 1983 of a development plan, construction of new telescopes in the newly recognized Science Reserve resumed. Between 1986 and 1999 the submillimeter array, the Keck telescopes, the Very Long Baseline radio antenna (VLBA), the Subaru, and Gemini telescope were completed (Pickles 2003:46). Farther downslope, several observatory-related projects have also involved additions or modification of facilities at Hale Pōhaku, including building of a dormitory for Subaru personnel. The stone cabins built by the CCC in the 1930s remain in place.

Increased access to the mountain and the need to evaluate the consequences of the development of the observatories has led to a number of cultural resource and environmental studies during the past 30 years. This research has included an intensive archaeological study of the Mauna Kea Adze Quarry by Bishop Museum under the direction of Patrick McCoy beginning in 1975 and 1976, archaeological surveys of the summit and extensive areas on the south side of the mountain, and the biological discovery and study of the rare *wēkiu* bug.

In 2002 the Keck Observatory and NASA proposed the construction of six 2-m-class telescopes to enhance the resolution of the Keck telescopes. The proposed project would join a complex of highly sophisticated astronomical observatories and contribute to the world-class significance of the astronomical information produced by investigations at the summit of Mauna Kea.

III. Identification of Burial Sites

MAUna Kea Science Reserve burials

Previous archaeological surveys of the Mauna Kea Science Reserve have documented numerous cultural resource sites, some of which have been identified as human burials. Oral history investigations document that there have been many other burials, including subsurface interment or burial as well as aerial dispersal of cremated human remains. This section of the Burial Treatment Plan identifies the areas where known burials have been reported (McCoy 1999). Five burial locations have been recorded as State of Hawai‘i archaeological sites (Table 1 and as shown on Fig. 2).

Figure 2: Burial locations on map of Mauna Kea Science Reserve (this figure has been withheld from publication in conformance with provisions of State of Hawai`i and Federal law)

Table 1: Burials and possible burials included in site list from McCoy (1999:Table1).

State Site No.	Elevation (ft. asl)	Description	Function
16195		2 cairns	possible burial
16248		series of cairns	burial
21413		cairn	possible burial
21414		cairn	possible burial
21416		cairn	possible burial

McCoy has conducted archaeological reconnaissance surveys in the Mauna Kea Science Reserve since 1979. Recently he updated much of this work for the Mauna Kea Science Reserve Master Plan (McCoy 1999). In that document, he defined a number of site types, as discussed in the background section of this Burial Treatment Plan. Among those definitions he included a type for known burials, as "a deliberate or intentional interment of human remains" and added, "all of the known and suspected burials in the Science Reserve are located in cairns situated on the tops of cinder cones" (McCoy 1999:3). He further discussed "Burials and Possible Burials - There are numerous references to human burials on the northern and eastern slopes of Mauna Kea, some at elevations that would fall within the boundaries of the Science Reserve (see discussion in McEldowey 1982)"(1999:25). Of these however, he asserted that "to date the only positively identified human remains found in the Science Reserve are located at Site 16248 on the

summit of Pu'u Makanaka (Fig. 1). Jerome Kilmartin, a surveyor with the United States Geological Survey, noted the presence of human remains on this prominent cinder cone in 1925"(1999:26).

McCoy differentiated stone markers, which may have commemorated visits to summit localities, from burials, which appeared to McCoy to have been associated with the top of cinder cones. Site 16195 was recorded on the eastern rim of Pu'u Lilinoe. McCoy proposed that this burial may have been among those reported by Alexander in 1892:

> The same afternoon (July 25, 1892) the surveyors occupied the summit of Lilinoe, a high rocky crater, a mile southeast of the central hills (the "summit") and a little over 13,000 feet in elevation. Here, as at other places on the plateau, ancient graves are to be found. In olden times, it was a common practice of the natives in the surrounding region to carry up the bones of their deceased relatives to the summit plateau for burial.

Sites 21413, 21414, and 41416 consisted of single cairns, and are located on the southeastern rim of a cinder cone on the northwestern edge of the Science Reserve. These

appeared to McCoy to be similar in form and location to the burial reported at Site 16195. In his report, McCoy discusses in detail the potential for additional burials in the Science Reserve:

> There is good reason to expect that more burials are to be found in the Science Reserve on the tops of cinder cones, either in cairns or in a small rockshelter or overhang. The basis for this prediction is that all of the known and suspected burial sites on the summit plateau are located on the tops of cinder cones and, more particularly, on the southern and eastern sides. No burials have been found on the sides or at the base of a cone, or on a ridgetop amongst any of the shrines. There in fact appears to be a clear separation between burial locations and shrine locations.
>
> The apparent restriction of the higher elevation burials to the apex of cinder cones is in sharp contrast to many of the burials found at Kanakaleonui, a well-known burial center located not too far outside of the Science Reserve, just below Pu'u Makanaka and the summit plateau, which is the lower boundary of the proposed Mauna Kea Summit Historic District. Reconnaissance of this area indicates that there are indeed a great number of structural remains at this locality. There are platforms on the top of the cone and a great number of smaller cairns at the base. On current evidence there are more burials in the general environs of Kanakaleonui than probably exist higher on the mountain, possibly on all of the summit plateau. The disproportionate number of burials in the environs of Kanakaleonui suggests that the edge of the plateau might have been a major social boundary, with the area below reserved for commoners and the plateau for persons of higher social status (chiefs and priests). If the very top of the cones were reserved for higher status individuals and the ground below for commoners, then Kanakaleonui must have both"(McCoy 1999:28).

Following this reasoning, then each of the cinder cones throughout the District could have burials not only at their summit, as earlier proposed by McCoy, but also on the lower slopes as found on Kanakaleonui, apposite McCoy's conclusion. Nonetheless, in his judgment, the only "known" burials were found at Sites 16195, 16248, 21413, 21414, and 21416 as reported in the Table 1 and Figure 2, above.

Outrigger Telescopes Site

No burials have been found or reported specifically in the area impacted by construction of WMKO, the area within which the Outrigger Telescopes will be built. The area has been graded level and a significant volume of cinders at the top of the *pu'u* was removed for the Keck Telescopes. The areas proposed for on-site construction, installation, and operation of up to six Outrigger telescopes as part of the Outrigger Telescope Project have already been severely degraded.

In reviewing the results of previous construction at the site, the SHPD has concurred with NASA's conclusion that the removal of as much as 34 feet of earth from the top of this site during the construction of Keck I effectively precludes the presence of burials. However, the nature of the leveling that went on during construction of Keck II is less clear and leaves it uncertain whether burials might still be present at moderate depths in this portion of the WMKO site. SHPD concludes that, if ground surfaces still exist that were only superficially altered, then there remains a possibility that burials might be present and that provisions for treatment of such burials should be developed (Hibbard 1999).

Based on the extensive disturbance, archaeological inventory or testing of terrain, as recommended by the Historic Preservation Plan for Mauna Kea (McEldowney 1999:9-10) would not be appropriate. However, given the possibility that human remains might be present despite the disturbance, cultural and archaeological monitoring, as recommended in the Historic Preservation Plan and the EA and MOA for the project, should be conducted, and a Burial Treatment Plan (this document) should be submitted to the Hawai‘i Island Burial Council and SHPD for their review and concurrence in advance of any construction activities.

IV. Recognition of Lineal and Cultural Descendants

Documentary Research and Oral History Interviews

The Mauna Kea Science Reserve has been the focus of several comprehensive studies of documentary and oral history investigations. Maly (1998, 1999, as well as recently updated versions of these reports 2004, in preparation) has conducted the most recent effort. He interviewed numerous individuals with long-term relationships and special knowledge of the Mauna Kea summit and native Hawaiian cultural practice. Some of this information is incorporated in the background information presented in this plan. As an outcome of his exhaustive work, Maly identified one certain burial site, as documented by W.D. Alexander (1892b). This site is the same recorded as Site 16195 by McCoy (1999).

publication of legal notices

The following notice will be published in papers of local and statewide distribution, requesting information from any persons with knowledge about burials at the WMKO site. The proposed text of legal notice would be as follows:

Public Notice

Notice is hereby given that burial sites may be located on a Hawai‘i Island land parcel, the W.M. Keck Observatory in the University of Hawai‘i Astronomy Precinct, owned by the State of Hawai‘i, that lie within the Mauna Kea Science Reserve on the summit of Mauna Kea. The proposed Outrigger Telescopes Project is proposed for construction at this site. The Project consists of the construction, installation, and operation of up to six 1.8 m diameter telescopes placed around the existing Keck Telescopes on the area of the cinder cone, Pu‘u Hau ‘Oki, that was previously disturbed for construction of the two Keck Telescopes. The project area is located in TMK: Zone 4, Sec. 4, Plat 15.

An archaeological survey has located five sites identified as Sites 50-10-15-16195, 16248, 21413, 21414, and 21416 that are thought to have been burial sites within the Mauna Kea Science Reserve on the summit of Mauna Kea. This land covers 11,288 acres leased by the University of Hawai‘i from the State of Hawai‘i. In addition, individuals who are known to have cultural association with the general area have been contacted directly, and these have

identified burial locales in the Mauna Kea Science Reserve Proper treatment of the burials shall occur in accordance with Chapter 6E, HRS, regarding unmarked burial sites. The property owner intends, to the extent practicable, to preserve in place, in accordance with a plan to be approved by the Hawai‘i Island Burial Council, the burials present within the property. A Burial Treatment Plan is being prepared by International Archaeological Research Institute, Inc. Final decisions regarding burials shall be made by the Hawai‘i Island Burial Council.

The Hawai‘i Island Burial Council requests that descendants of those who may have been buried in the aforementioned property and who may have knowledge regarding these remains or others in the area to immediately contact Mary Perzinski (808) 587-0040 and/or Kana‘i Kapeliela (808) 692-8037 of the State Historic Preservation Division on O‘ahu within 30 days of this notice to present information regarding appropriate treatment of the human remains. Responding individuals must be able to adequately demonstrate lineal descent from the Native Hawaiian remains, or cultural descent from ancestors associated with the burials on the summit of Mauna Kea where the graves are located.

Consultations

Notification of consultations is pending publication of notice and response period.

V. Proposed Treatment

Preservation Plan

In keeping with the Historic Preservation Plan prepared for the Mauna Kea Science Reserve (McEldowny 1999), each individual historic property may have significance, but also each property contributes to the Historic District as a whole. Therefore, the significance of individual properties located within the district requires evaluation and treatment “collectively and within the context of the summit’s natural landscape”(1999:3). For burials, which are both historically as well as culturally significant, preservation in place is the preferred treatment.

The Historic Preservation Plan requires that inventory, testing, and mitigative treatment be conducted before any project development in the Mauna Kea Science Reserve (McEldowney 1999:7-10). In areas that are already disturbed and where the terrain is no longer intact, the Plan recommends archaeological and cultural monitoring. Procedures for monitoring and compliance with the requirements for inadvertent discovery of burials are provided in Chapter 6E-43.6 (HRS) and administrative rule 13-300-40, and also in the “Mitigation and Monitoring Measures for the Outrigger Telescopes Project (Appendix G, Environmental Assessment for the Outrigger Telescopes Project, Mauna Kea Science Reserve, Island of Hawai‘i).

In-place preservation would be the preferred treatment, where practicable, and this would be achieved through the establishment of defined preservation buffers. (described below).

Preservation site buffers

A buffer zone of 6.1 m (20 ft) will be established around the perimeters of burial sites except where this is incompatible with the Outrigger Telescopes Project design. Where a 6.1-m buffer zone would be incompatible with the Project design, either a smaller buffer zone will be established or the burial will be relocated. No land disturbing activity will occur within the buffer zones.

inadvertent burial discoveries

This section of the Burial Treatment Plan provides guidelines and procedures for dealing with the inadvertent discovery of human remains during any activity at the Mauna Kea Science Reserve. The guidelines and procedures follow HRS 6E-43.6 (entitled "Inadvertent Discovery of Burial Sites") and the DLNR Administrative Rules Section 13-300-40.

Construction Monitoring

In order to insure recognition and proper treatment of any burial remains that may be inadvertently discovered during construction, construction activities will be monitored by an archaeologist and a cultural monitor, in accordance with the stipulations of the Memorandum of Agreement (MOA) prepared in connection with the Environmental Assessment for the Outrigger Telescopes project. NASA will be responsible for insuring that monitoring is undertaken as stipulated in the MOA.

During Construction

The following actions will be taken during all ground alteration activities.

1. An archaeological monitor will be present during all ground alteration activities, such as grading, grubbing, and excavation during any construction activities in the project area.

Following Construction

Following ground alteration activities, the professional archaeologist will prepare a report that meets all requirements of SHPD Administrative Rules 13-279-7, as well as documents (1) the measures taken to implement short-term preservation measures for burials and (2) any new burials that may hay have been uncovered. This report will be submitted to the SHPD.

Procedure for Inadvertent Burial Discoveries

SHPD Administrative Rules 13-300-40 lay out the procedure for inadvertent discoveries of human remains. In the event that previously unknown human remains are exposed during any action related to the development of the Mauna Kea Science Reserve, all

work in the vicinity of the burial site shall cease (although work may continue in other areas of the development) and the remains shall be left in place and protected from further damage. Human remains may also be inadvertently exposed by natural events, such as storm erosion.

The SHPD Hawai‘i Island archaeologist, the Hawai‘i County Police Department, and the Hawai‘i County medical examiner coroner shall be notified. The SHPD will inform the representative of the Hawai‘i Island Burial Council of the discovery and the time that a site visit will be made. The Police Department has jurisdiction if the remains appear to be less than 50 years old; the SHPD has jurisdiction if they appear to be more than 50 years old.

If the remains are more than 50 years old, SHPD has three days to determine if they should be preserved in place or relocated. Remains shall be relocated if preservation in place is incompatible with the Project design. The SHPD determination will be made in consultation with landowners, any known lineal or cultural descendants, and appropriate ethnic organizations. When practicable, remains shall be preserved in place. If relocation is required, then provisions of this Burial Treatment Plan will be followed.

Once appropriate measures have been taken for protection or removal of the remains, development work in the area can resume.

Long-Term Preservation Treatment

Long-term preservation requirements address potential impacts from on-going use and occupation of the Mauna Kea Science Reserve.

1. All inadvertently discovered burial sites, whether in place or removed, will be set aside as preserves and will include a buffer zone that recognizes the surrounding landscape context of the site, although it will be a minimum of 6.1 m (20 ft) unless a buffer zone of such size is incompatible with the Project design. The site boundaries will be defined by an in-field evaluation of the relationship among described features and any surrounding undocumented features. Terrain features such as steep slopes that could act as a natural buffer will be considered in the final definition of buffer widths.

2. The burial site will be defined by berms, walls, or a combination of these elements, so long as there is no adverse effect on the historic property and historic district. The purpose of this physical delineation is to clearly define the site and buffer boundaries and to protect the site from potential harm from unauthorized access. The physical barriers will be of such design that blends with the surrounding area.

3. Perpetual access to burial sites shall be granted to known lineal or cultural descendants.

maintenance and security

Responsibility for maintenance and security of the burial site would lie with the University of Hawai‘i. Actual implementation could be placed in the hands of the Office of Mauna Kea Management or a successor organization, if any, that assumes its responsibilities.

Long-term/permanent in-place preservation would be achieved by a means of a Memorandum of Agreement between the Hawai‘i Burial Council and the California Association for Research in Astronomy, project manager, which would include the appropriate requirements and restrictions relating to physical improvements, maintenance, security, and access by recognized lineal and/or cultural descendants.

Access for Lineal and/or Cultural Descendants

Access to the burial site for appropriate cultural activities would be permitted to any lineal and/or cultural descendant formally recognized by the HIBC or DNLR-SHPD in accordance with the administration procedures contained within Section 13-300-35: “Recognition of lineal and cultural descendants (DLNR 1006). Specific arrangements for access would be made by direct, mutual agreement between the University of Hawai‘i and recognized lineal and/or cultural descendants.

VI. Implementation of the Burial Treatment Plan

Preservation measures contained in the Burial Treatment Plan would be implemented by the California Association for Research in Astronomy, project manager, following receipt by the applicant of DLNR written confirmation of mutual agreement to these measures.

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APPENDIX D

Wēkiu Bug Mitigation Plan

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APPENDIX D WĒKIU BUG MITIGATION PLAN

Errata Sheet
July 28, 2004

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APPENDIX D WĒKIU BUG MITIGATION PLAN
ERRATA

Item 1: Wekiu bug habitat will be restored … (page 2). The 2nd paragraph under Item 1 is changed to read:

NASA and CARA have proposed Wēkiu bug habitat restoration in three areas within Pu‘u Hau ‘Oki that were previously damaged by observatory construction (Figure 1). The proposed restoration effort would encompass an area greater than 0.028 ha (0.069 ac), resulting in a habitat restoration of at least 3:1 relative to the amount of habitat that would be displaced by on-site construction and installation of Outrigger Telescopes 2 and 3. Restoration of the areas adjacent to JB5 and Outrigger Telescope 1 will be given equal priority to restoration of the area on the floor of Pu‘u Hau ‘Oki crater. Since the size of the restoration area will be limited by the amount of available cinder excavated during construction of the Outrigger Telescopes, the size of the restoration area on the floor of Pu‘u Hau ‘Oki crater may be reduced in order for areas adjacent to JB5 and Outrigger Telescope 1 to be restored. Restoration will continue until the supply of suitably-sized cinder is exhausted , or the restoration of all three areas is complete.

Item 12 (b): Contractors will be required to inspect … (page 7). The paragraph under Item 12 (b) is changed to read:

Prior to entry into the Mauna Kea Science Reserve, all large trucks, tractor-trailer rigs, earthmoving machinery, and other heavy equipment shall be inspected by a trained biologist, who shall certify that all large trucks, tractor-trailer rigs, earthmoving machinery, and other heavy equipment were inspected for flora and fauna that may potentially have an impact on the Mauna Kea summit ecosystem. This inspection will be recorded in the contractor’s logbook.

Item 13 (b): Contractors will be required to inspect … (page 8). The first sentence in the 2nd paragraph under Item 13 (b) is changed to read:

Prior to entry into the Mauna Kea science reserve, all construction materials, equipment, crates, and containers carrying materials and equipment, shall be inspected by a trained biologist, who shall certify that all materials, equipment, and containers were inspected for flora and fauna that may potentially have an impact on the Mauna Kea summit ecosystem.

Item 16: Construction contracts will ensure … (page 9). The following is added to the paragraph:

To further ensure contractor compliance to mitigation procedures, CARA will implement the Wēkiu Bug Monitoring Plan.

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Wēkiu Bug Mitigation Plan

December 14, 2001

Wēkiu Bug Mitigation Plan

The following plan is based on recommendations provided by natural resource consultants at Pacific Analytics in the Wēkiu Bug Mitigation Report (Pacific Analytics 2000) (revised November 4, 2000) to restore habitat, and to prevent and mitigate impacts to the cinder slopes below the W. M. Keck Observatory (WMKO) complex during on-site construction, installation, and operation, as appropriate, of the proposed Outrigger Telescopes (Pacific Analytics 2000). (Numbers in parentheses after each commitment refer to the corresponding Pacific Analytics recommendation number.) It is the intention and hope that the Wēkiu bug population will actually **increase**, due to protection and restoration of potentially favorable habitat.

1. Wēkiu bug habitat will be restored in areas damaged by on-site Outrigger Telescope construction, and on the crater floor of Pu‘u Hau ‘Oki. Restored areas will total at least three times the total area damaged by new construction. (IV-1)

Areas damaged by new construction will be restored to the extent possible. This will not be possible in areas where new construction covers existing Wēkiu bug habitat with concrete foundations of junction boxes, air pipes, light tunnels, and retaining walls. Restoration of habitat of an area at least three times the area newly damaged will aid in enhancing the Wēkiu bug population in the crater. Material obtained from project excavations not used for backfill will be trucked to the temporary stockpile area where it will be screened and washed and all suitable material returned to Pu‘u Hau ‘Oki to be used for Wēkiu bug habitat restoration. All excavation material not directly used as fill or for Wēkiu bug habitat restoration will be placed on the mountain at locations to be determined after consultation with the State Historic Preservation Division (SHPD) and the Office of Mauna Kea Management (OMKM).

NASA and CARA have proposed Wēkiu bug habitat restoration within a portion of the crater bottom that was previously damaged by observatory construction on Pu‘u Hau ‘Oki. The proposed crater bottom restoration area is almost large enough to accomplish the proposed 3:1 restoration goal. Restoration of this area would be followed by restoration of the sloped crater wall habitat that would be disturbed by on-site construction of JB-5 at Outrigger Telescope 2. A third potential habitat restoration area has been identified at Outrigger Telescope 1. This third potential restoration area could be used in future restoration efforts or if the crater bottom restoration effort does not yield sufficient area to attain the 3:1 goal.

Restoration habitat will be composed of screened cinder larger than 1.3 centimeters (cm) (1/2 inch), washed with water to remove ash. Cinder will be spread 30 cm to 46 cm (12 to 18 inches) deep in the restoration areas, and will form a complete interface with cinder in adjacent Wēkiu bug habitat. It may be necessary that cinder be spread more than 46 cm (18 inches) deep in some places, in order to assure the necessary contact with existing habitat.

Screened and washed cinder may be emplaced on the crater floor by partial tilting of the dump bed while the truck is slowly moving. No further working of the screened cinder is required; uneven deposition will make better habitat than an evenly spread or compacted surface. No preparation of the crater floor prior to deposition is required.

The non-permanent barrier blocking vehicle access to the crater floor will be removed to allow transport of the screened cinder into the crater floor. The barrier will be replaced after installation of the restored habitat.

Attractive, non-intrusive, educational signs will be installed near the crater access point along the adjacent service road, (see commitment 3). The signs will have information about Wēkiu bugs and their habitat. (Signs will help prevent unintentional disturbance of habitat by visitors to the summit.). Design of the signs will be consistent with the guidelines presented in the Mauna Kea Science Reserve Master Plan. Prior to installation, sign design and specifications will be submitted to both the Department of Land and Natural Resources (DLNR) and to OMKM for approval.

2. Under no circumstances during construction, installation, and operation will cinder or other materials be side-cast into Wēkiu bug habitat. Temporary barriers will be built along the slope breaks above the inner slopes of Pu‘u Hau ‘Oki crater. (IV-2)

Prior to any construction activities, temporary 3-foot high silt fences will be installed along the rim of the Pu'u Hau Oki crater, where excavation or trenching is planned to take place within six feet of the slope to contain cinder on the site. The temporary silt fences will be maintained by the contractor on a daily basis to repair any damage to the fence.

3. Educational signs will be placed along the slope break above Wēkiu bug habitat, and at the service road adjacent to the crater floor. (IV-3)

Many places along the WMKO leveled site provide special scenic vistas. There are foreground views into the Pu‘u Hau ‘Oki crater, midground views of the summit area, and background views of the entire Island and beyond. These vistas are unique and among the reasons people visit the summit.

Attractive, non-intrusive, educational signs will be installed to inform people about Wēkiu bugs and their habitat. Signs will help prevent unintentional disturbance of habitat by workers and visitors. Design of the signs will be consistent with the guidelines presented in the Mauna Kea Science Reserve Master Plan. Prior to installation, sign design and specifications will be submitted to both the Department of Land and Natural Resources (DLNR) and to OMKM for approval.

4. Water will be applied to excavation sites and cinder stockpiles. (V-1)

Proposed excavation and construction activities will disturb less than one-half acre of the WMKO leveled site during the construction period. Water will be applied to excavation sites and cinder stockpiles during all earthmoving activities.

Construction contractors typically spray water as needed to minimize airborne particulate matter. Potable water is currently transported to the WMKO from Hilo in tankers capable of carrying up to 19 kiloliters (5,000 gallons) per trip. Potable water for dust suppression will also be transported to the site and applied as needed during trenching, bulldozing, or other soil disturbance activities.

The applied water is not expected to cause any negative impact to the Wēkiu bug, and may actually be beneficial. It is possible that the application of water to excavation sites could increase the amount of moisture available for Wēkiu bugs.

5. Dust-generating activities will be suspended during high winds. (V-2)

Storms and accompanying high winds can arise quickly at the summit. These winds are capable of raising dust from recently exposed cinder and ash. Dust-generating activities will be suspended during periods of high winds, and water will be applied to recently exposed cinder and ash.

6. Soil-binding stabilizers will be used sparingly, and will never be applied to Wēkiu bug habitat. (V-3)

Vehicle traffic to WMKO is expected to increase during and after construction of the Outrigger Telescopes. Environmentally-safe soil stabilizers may be applied to road and parking areas to reduce dust during and after on-site construction. Soil stabilizers may be needed to reduce dust during the excavation of Outrigger Telescope foundations and light tunnels. Environmentally-safe soil stabilizers will only be used where the application of potable water is inadequate for dust control. In no case will soil stabilizers be applied directly to Wēkiu bug habitat slopes, nor will they be applied to excavated cinder that is to be used in mitigation habitat. Application of soil stabilizers will be performed under light wind conditions to prevent drift into Wēkiu bug habitat.

Soil stabilizers are often applied to roads to improve stability and suppress dust. Generally, the stabilizers bind soil particles together to form a hard, protected surface. There are many commercially available dust control additives, each with characteristics specific for soil types, climate conditions, and road uses. They also differ in soil penetration potential, suppression duration, and costs. All of these factors will be considered before a soil stabilizer treatment is applied.

Several dust-suppressing soil stabilizers are considered “environmentally friendly” and appear to be free of residuals that can harm native arthropod populations. Most have been

tested for toxicity on micro-invertebrates, fish, and wildlife. Professional review before application of soil stabilizer products will reduce the chances of inadvertent impacts to Wēkiu bug habitat. An entomologist familiar with Wēkiu bug autecology will review the potential impacts of products being considered for use, and make recommendations. In no case will soil stabilizers be used indiscriminately, nor will they ever be applied beyond the slope break of the observatory site.

Soil stabilizers are not always appropriate for dust control. An alternative to soil stabilizers is the application of potable water to roads and construction site surfaces. Dust control watering could potentially increase water availability to Wēkiu bugs, enhancing survival and population growth.

7. The WMKO staff will continue to follow Federal guidelines specifying the use and disposal of substances used in the washing and recoating of observatory mirrors. (VI-1)

The WMKO 10-meter mirrors are made up of 36 segments, each approximately 1.8 meters (6 feet) in diameter. The proposed Outrigger Telescopes will use mirrors 1.8 meters (6 feet) in diameter. Under standard operating procedures, up to four mirror segments can be recoated in each month. Outrigger Telescope mirrors will be recoated on a similar schedule. The proposed additional four to six Outrigger Telescope mirrors will thus increase the total mirror surface area to be processed by 6 to 8 percent. Mirror recoating effluents at WMKO will be collected, and removed and transported off-site by a licensed waste handler.

8. Contractors will be required to minimize the amount of on-site paints, thinners, and solvents. Painting and construction equipment will not be cleaned on-site. Contractors will be required to keep a log of hazardous materials brought on-site and report spills immediately to a designated WMKO representative. (VI-2)

Many components of the proposed Outrigger Telescopes will arrive at the site ready for installation. Some components may require painting. Paints, thinners, and solvents are toxic to Wēkiu bugs. The amounts of such substances transported to the summit will be those required to support the current activity. The amount required for the entire project will not be stockpiled on the summit.

Cleaning paintbrushes, rollers, and paint-spraying equipment requires the use of solvents and thinners. Having these substances on-site increases the risk of spills. Painting equipment will be cleaned off-site to reduce the risk of spills that could impact Wēkiu bug populations.

Contractors will be required to keep a weekly log of hazardous materials they bring to the site. The log will consist of a list of the substances that are being used, and the number

and size of the containers that arrive and leave the site. The log will be available for inspection by CARA representatives.

In the unlikely event of an accidental spill of hazardous materials, it will be reported immediately, and appropriate actions will be taken to limit the impact to Wēkiu bugs. Spills will be contained to limit the impact area, and if the spill results in soil contamination, the soil will be removed in a safe and effective manner. Logs and manifests can provide useful information regarding the hazardous materials on site, in case of an accidental spill.

9. Construction trash containers will be tightly covered to prevent construction wastes from being dispersed by wind. (VII-1)

Covering containers will decrease the amount of construction debris that could be blown onto Wēkiu bug habitat. "Roll off" containers will be equipped with secure tops and lids to ensure no debris escapes during high winds. Containers will be collected on a regular basis before they are completely full or overflowing. This could entail collection several times a week, particularly during periods of heavy use.

10. Construction materials stored at the site will be covered with tarps, or anchored in place, and not be susceptible to movement by wind. (VII-2)

Construction materials and supplies will be prevented from being blown into Wēkiu bug habitat by covering them with heavy canvas tarps. Steel cables, attached to anchors that are driven into the ground, can hold materials down.

Construction materials at the site will be tied down or otherwise secured during high winds and at close of work each day. Securing materials will reduce the chances of debris being blown off the site into Wēkiu bug habitat. Preventing debris from blowing onto the habitat slopes will reduce costs and potential habitat disturbance necessary to retrieve the items.

11. If construction materials and trash are blown into Wēkiu bug habitat, they will be collected to the extent practicable, with a minimum of disturbance to the habitat. (VII-4)

Despite efforts to prevent wind-blown construction materials and trash, some debris could end up in Wēkiu bug habitat. Retrieving this debris from sensitive areas will be done carefully and with minimum disturbance. Small pieces of debris will be allowed to blow out of Wēkiu bug habitat to spots where they can be collected safely. Larger debris will be removed with minimum disturbance to slope stability and structure. Methods for removal may vary depending on the material and its location. Contractors will be educated about appropriate debris retrieval methods.

12. Earthmoving equipment will be free of large deposits of soil, dirt, and vegetation debris that could harbor alien arthropods. (VIII-1)

(a) Contractors will be required to pressure-wash earthmoving equipment to remove alien arthropods.

Alien arthropods can arrive at the summit by two general pathways. First, alien species already on the Island can spread to new localities. Second, alien species can arrive with shipping crates and containers. In order to block the first pathway, heavy equipment, trucks, and trailers will be pressure-washed before being moved to the construction site at Puʻu Hau ʻOki.

Earthmoving equipment and large vehicles and trailers often sit at storage sites for several days or weeks between jobs. Most of these storage sites are located in industrial areas and usually support colonies of ants and other alien arthropods. These species often use stored equipment as refuges from rain, heat, and cold. Ants will colonize mud and dirt stuck to earthmoving equipment and could then be transported to uninfested areas. Spiders occupy stored equipment, looking for food or escaping predation by hiding in protected niches. Once transported to the summit, these species could migrate to Wēkiu bug habitat.

Pressure-washing of equipment before transportation to the construction site at Puʻu Hau ʻOki will remove dirt and mud and wash away ants, spiders and other alien arthropods, thereby reducing the chances of transporting these species to the summit area.

(b) Contractors will be required to inspect large trucks, tractors, and other heavy equipment before proceeding up the observatory access road.

Tractor-trailer rigs, earthmoving machinery, and other heavy equipment will be inspected for arthropods before proceeding up the observatory access road. This inspection will be recorded in the contractor's logbook.

13. All construction materials, crates, shipping containers, packaging material, and observatory equipment will be free of alien arthropods when delivered to the summit. (VIII-2)

(a) Contractors will be required to inspect shipping crates, containers, and packing materials before shipment to Hawaiʻi.

Alien arthropods can be transported to Hawaiʻi via crates and packaging. Contractors will be requested to use only high quality, virgin packaging materials when shipping supplies and equipment. Pallet wood will be free of bark and other habitat that can facilitate the transport of alien species. WMKO managers will communicate to shippers, and suppliers the environmental concerns regarding alien arthropods, and inform them about

appropriate inspection measures to ensure that supplies and equipment shipped to Hawai‘i are free of alien arthropods at the points of departure and arrival.

Shipping containers will be inspected and any visible arthropods removed. Construction of crates immediately prior to use will prevent alien arthropods from establishing nests or webs. Cleaning containers just prior to being loaded for shipping will also eliminate alien arthropod infestations.

Many arthropods may escape detection during shipping inspections. After arrival in Hawai‘i, crates or boxes to be transported to the summit will be re-inspected for spider webs, egg masses, and other signs of alien arthropods. Re-inspection prior to transport to the summit will reduce the potential for undetected alien arthropods reaching the summit.

(b) Contractors will be required to inspect construction materials before transport to the summit area.

Alien arthropods already resident in Hawai‘i are capable of hitchhiking on construction material such as bricks and blocks, plywood, dimensional lumber, pipes, and other supplies. Precautions will be taken to ensure that alien arthropods are not introduced to the Mauna Kea summit area.

Construction materials will be inspected before transport to the construction site. If any alien arthropods are discovered, the infestation will be removed prior to transport. Infestations of ants can be removed using pressure-washing. Infestations of spiders can be removed using brooms, vacuum cleaners, or other similar methods. Pesticide use on materials to be transported to the summit will be avoided.

14. Outdoor trash receptacles will be secured to the ground, have attached lids and plastic liners, and be collected frequently to reduce food availability for alien predators. (VII-3 & VIII-3)

Workers and visitors to the WMKO inevitably often bring some trash with them. Lunch bags, film canisters, wrappers, etc. can be easily blown into Wēkiu bug habitat. Receptacles will be provided to eliminate the dispersal of this kind of trash. The receptacles will be heavy and have attached lids so that they do not become flying objects in the high winds at the summit.

Readily available food supplies can facilitate the establishment of alien arthropods at the summit. Sanitary control of food and garbage will prevent access to food resources that could be used by invading ants and yellowjackets.

Refuse containers will be heavy and secured to the ground. Refuse will be collected on a regular basis before containers are completely full or overflowing. This could entail collection several times a week, particularly in eating areas and during periods of heavy use of the area.

Containers will be regularly washed using steam and/or soap to reduce odors that attract ants and yellowjackets. Plastic bag liners will be used in all garbage containers receiving food to control leaking fluids.

15. New alien arthropod introductions detected during monitoring will be eradicated. (VIII-4)

(a) Ant eradication

Sticky traps designed to capture ants will be deployed immediately after any ants are detected. Persistence of ant detections is indicative of larger infestations, and will prompt a search for and eradication of colonies. Bait and chemical control will be employed only when absolutely necessary and only by a certified pest control professional. In no case will pesticides be applied on or near restored habitat or crater slopes.

(b) Yellowjacket eradication

Traps will be deployed when yellowjackets are detected. Trapping yellowjackets is a useful method of control that does not require pesticides. Lures or baits will improve the effectiveness of traps. Localized yellowjacket populations can be reduced to non-threatening levels if trapping is employed immediately after detection. Traps will be maintained until yellowjackets are no longer detected.

(c) Alien spider eradication

Alien spider webs will be removed when detected. Native lycosid wolf spiders do not make webs. Native sheet-web spiders make tiny webs under the cinder surface. Only alien spiders make large spider webs at the WMKO site. Sweeping such webs away with a broom disrupts alien spider food capture success and destroys egg masses.

16. Construction contracts will ensure that compliance violations are corrected.

The commitments in this Mitigation Plan will become, as applicable, rules and guidance for contractors and operators during on-site construction, installation, and operation of the proposed Outrigger Telescopes, light tunnels, and retaining walls. This will be accomplished through appropriate contract provisions and CARA oversight of contractor activities. A well-designed monitoring plan will detect violation of the rules and guidance. Such a plan has been developed and will be implemented when construction begins. Violations or other errors will be corrected as soon as possible in a manner that protects and enhances Wēkiu bug population and habitat.

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APPENDIX E

Wēkiu Bug Monitoring Plan

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APPENDIX E WĒKIU BUG MONITORING PLAN

Errata Sheet
July 28, 2004

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APPENDIX E WĒKIU BUG MONITORING PLAN
ERRATA

12. Section 3.1 – Introduction (page Effectiveness Monitoring - 1). The following is added after the last paragraph in this section:

NASA and CARA will implement the Wēkiu Bug Monitoring Plan, and restored habitats will be monitored quarterly by a qualified entomologist for 18 months following completion of the proposed habitat restoration to determine if the Wēkiu bug reestablishes in those areas. Monitoring of Wēkiu Bug populations shall continue biannually for no less than five (5) years following completion of the construction of the Outrigger Telescopes, and on an annual basis thereafter for the term of the CDUP. Additionally, efforts will be made to reduce the field study mortality of Wēkiu bugs to less than forty percent (40%). Progress reports on the efforts to reduce the field study mortality rate and monitoring results shall be submitted biannually to the Department of Land and Natural Resources, the Office of Mauna Kea Management, and the Bishop Museum for no less than five (5) years following completion of construction of the Outrigger Telescopes, and on an annual basis thereafter for the term of the CDUP.

13. Section 3.3 – Population Change Module; Question of Interest 3.3.1, Sampling Systems (page Effectiveness Monitoring – 3 - 4),

a. Sampling Intensities, 3.3.1A1 and 3.3.1B1) is changed to read:

3 pitfall traps in each location of restored habitat.

b. Sampling Frequencies, 3.3.1A all and 3.3.1B all) the text within the parentheses is deleted:

14. Section 3.3 – Population Change Module; Reporting: 3.3.1A all and 3.3.1B all) (page Effectiveness Monitoring - 4). The first part of the sentence is changed to read:

Include in all Quarterly, Biannual, and Annual reports,

15. Section 3.3 – Population Change Module; Question of Interest 3.3.2, Reporting System: 3.3.2A all and 3.3.2B all) (page Effectiveness Monitoring - 7). The first part of the sentence is changed to read:

Include in all Quarterly, Biannual, and Annual reports,

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WĒKIU BUG MONITORING PLAN - TABLE OF CONTENTS

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WĒKIU BUG MONITORING PLAN

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Revised October 24, 2001

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OVERVIEW

1.1 - EXECUTIVE SUMMARY

The Mauna Kea Science Reserve is located on the summit of the tallest mountain in Hawai'i, (13,796 feet). Within the reserve are the world's two largest optical telescopes, constituting the W. M. Keck Observatory (WMKO). Directly adjacent to and below the WMKO is a unique natural environment that supports the Wēkiu bug, a rare insect found only in the extreme habitat of the Mauna Kea summit.

Current plans call for expanding the Keck Observatory by adding four Outrigger telescopes. These new telescopes will enhance the capabilities of telescopes by using a technique known as interferometry.

The National Aeronautics and Space Administration (NASA), through the Jet Propulsion Laboratory (JPL), together with the California Association for Research in Astronomy (CARA) and the University of Hawai'i Institute for Astronomy (IfA), have made a commitment to protect and enhance Wēkiu bug populations and habitat concurrently with construction of the new Outrigger Telescopes. To that end these collaborators have sponsored a Wēkiu Bug Mitigation Report from which they developed the Wēkiu Bug Mitigation Plan. They are also the sponsors of this Wēkiu Bug Monitoring Plan. Monitoring will help to assure all stakeholders that mitigation activities associated with the new construction will be beneficial to this rare insect.

Environmental monitoring is the scientific investigation of the changes in environmental phenomena that happen over time. This Wēkiu Bug Monitoring Plan describes the procedures necessary to implement an investigation of changes in Wēkiu Bug population and habitat adjacent to the WMKO during and after Outrigger Telescope construction.

This Monitoring Plan includes an Overview of Monitoring, (Section 1). Comprehensive discussions of the monitoring Questions of Interest are divided into Compliance and Effectiveness, (Sections 2 and 3). Data management, analysis, and reporting of monitoring findings are discussed in Section 4. A schedule may be found in Section 5. Protocols for data gathering are in Section 6.

1.2 - INTRODUCTION

The summit of Mauna Kea, on the Big Island of Hawai'i, is home to the largest observatory complex in the world. The summit is also home to unique plants and animals, including the Wēkiu bug. One of the principle habitats of this rare insect is directly adjacent to and below the Pu'u Hau Oki crater rim site of the W. M. Keck Observatory (WMKO).

This Monitoring Plan was developed to aid in protection and enhancement of the Wēkiu bug population. This Plan is consistent with the goal of good stewardship of the natural environment on the summit of Mauna Kea. The National Aeronautics and Space Administration, through the Jet Propulsion Laboratory, is the sponsor of this Monitoring Plan. The University of Hawai'i, the Institute for Astronomy, and the California Association for Research in Astronomy have provided significant assistance and collaboration.

Outrigger telescopes have been proposed as an addition to the WMKO. As part of that expansion project, three conservation programs have been recommended: mitigation, monitoring, and autecological studies.

Environmental mitigation is the protection and enhancement of natural resources. The Wēkiu Bug Mitigation Report, published under separate cover, recommends a mitigation program that will protect the Wēkiu bug population within Pu'u Hau Oki crater, and restore some of the habitat lost there in the past.

Environmental monitoring is the scientific investigation of the changes in environmental phenomena, attributes and characteristics that happen over time. Ecosystems are dynamic. Habitat conditions change daily, seasonally, and over longer periods of time. Animal and plant populations rise or fall in response to a host of environmental fluctuations. The general purpose of monitoring is to detect, understand, and predict the environmental changes.

JPL, NASA, CARA, and the IfA have made a commitment to do no harm to the Wēkiu bug population during the proposed construction and operation of the Outrigger Telescopes. In order to accomplish this, observatory planners and managers need scientific and reliable information about the Wēkiu bug, about the impacts of management actions to the habitat, and about changes in the population over time. Environmental monitoring is the best way to obtain that information.

This Monitoring Plan proposes methods for investigation of results of actions undertaken in the Mitigation Program, and the subsequent changes in the Wēkiu bug population and habitat. Two types of monitoring are necessary: compliance and effectiveness monitoring. This Plan specifies tasks, budgets, schedules, and methods for both types of monitoring. Compliance monitoring investigates the extent to which contractors, operators, managers, and visitors comply with Wēkiu bug protection guidelines and rules. Effectiveness monitoring investigates the changes in Wēkiu bug habitat and population that happen concurrently and subsequently to construction of the Outrigger telescopes. This includes monitoring of habitat restoration efforts.

The Monitoring Program will provide much of the data needed to protect and enhance natural resources, to modify management actions, to aid in compliance with environmental statutes, and to enhance public education and appreciation of the natural resources at the summit of Mauna Kea.

Monitoring alone, however, will not provide all the desired information about the Wēkiu bug. Additional autecological studies are also recommended. Autecology is the study of the patterns of distribution and abundance of individual species, together with the ecosystem structure and functions that influence distribution and abundance.

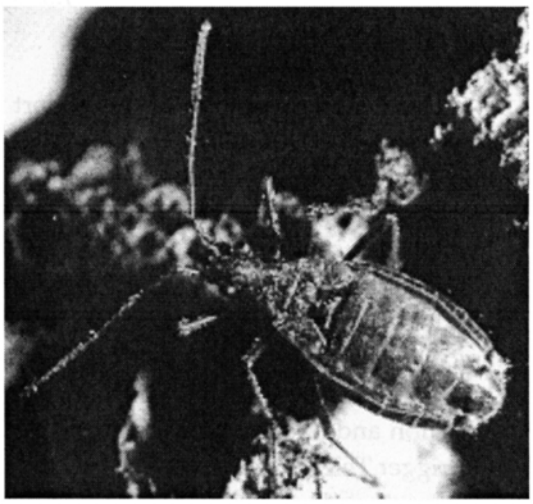


Figure 1 - 1. The Wēkiu bug, *Nysius wekiuicola*, native to the summit area of Mauna Kea. *Photo courtesy W.P. Mull.*

The three conservation programs, mitigation, monitoring, and autecological studies, together will provide the framework for protecting and enhancing the Wēkiu bug habitat and population on Mauna Kea. Lessons learned during the Outrigger Telescopes project will aid conservation efforts elsewhere on the summit, within the greater Mauna Kea Science Reserve, and on other mountaintops in Hawai'i.

1.3 - OBJECTIVES

The general objective of this report is to describe a Monitoring Program that aids in the protection and enhancement of the Wēkiu bug population and habitat adjacent to the W. M. Keck Observatory. The Monitoring Program will investigate the human activities and associated changes that occur to Wēkiu bug population and habitat during construction and operation of the proposed Outrigger Telescopes.

The Monitoring Plan is presented in sections and subsections. In the next subsection, 1.4 - Systematic Monitoring, we discuss the steps necessary to plan and implement monitoring. These steps apply to all the Questions of Interest (QOI's).

In the following two main sections, Section 2 – Compliance Monitoring, and Section 3 – Effectiveness Monitoring, we describe each recommended QOI in detail. The Compliance and Monitoring Sections are organized into modules:

Section 2 - Compliance Monitoring
- 2.1 Introduction
- 2.1 Listing of QOI's
- 2.3 Habitat Restoration Module
- 2.4 Slope Stability Module
- 2.5 Dust Module
- 2.6 Hazardous Materials Module
- 2.7 Trash Module
- 2.8 Alien Arthropods Module

Section 3 - Effectiveness Monitoring
- 3.1 Introduction
- 3.2 Listing of QOI's
- 3.3 Population Change Module
- 3.4 Habitat Module

This organizational structure allows for addition or deletion of component QOI's. As new knowledge is acquired about the Wēkiu bug, some QOI's may be satisfactorily answered and removed from the Program. New knowledge may also lead to new QOI's that can be added. In this way, the Monitoring Program is adaptable to new findings, needs, and conditions.

Discussions of data management, analysis, and reporting may be found in Section 4 - Results. A schedule for the Monitoring Program is given in Section 5 - Schedule and Budget. Protocols for data gathering are in Section 6 – Protocols.

1.4 - SYSTEMATIC MONITORING

Environmental monitoring is the investigation of the changes in environmental phenomena, attributes and characteristics that happen over time.

An investigation concerned only with measuring environmental phenomena, attributes, and characteristics at a single point in time is called an inventory. Monitoring is a series of inventories taken over time, repeated measurements taken in such a way as to be comparable with each other. Systematic monitoring is a monitoring program that follows a specified progression of tasks or steps to maximize the efficiency and utility of the investigation.

The Purposes of Monitoring

The most general purpose of environmental monitoring is to learn about the changes occurring in our natural world. This purpose may be subdivided into three more specific goals: to detect, predict, and understand those changes. Not all monitoring programs have all three of these goals, but all have at least one of them.

Every monitoring program has its own set of unique purposes, as well. These are usually one or more of the following, ranked in general order of increasing complexity and sophistication:

- To detect threshold events, or critical levels, of environmental phenomena, attributes, and characteristics.

- To detect specific changes in the environment.

- To detect hazards and risks to valued ecosystem attributes and functions and/or to the human communities that depend on them.

- To provide historical records of change in environmental phenomena, attributes, and characteristics.

- To detect trends, periodicities, cycles, and/or other patterns in those changes.

- To associate auxiliary phenomena, attributes, and characteristics with trends and patterns of change in key phenomena, attributes, and characteristics.

- To predict future changes in environmental phenomena, attributes, and characteristics.

- To link environmental changes to their causes.

Different monitoring programs may have different sets or combinations of these purposes. Clarity of purpose is important in planning monitoring programs. The more complex and sophisticated goals of establishing associations and cause-and-effect relationships typically require significantly more effort and expense than simple detection of change.

All these purposes of environmental monitoring involve increasing our knowledge and understanding. A closely related purpose of monitoring is to modify management actions. The new knowledge gained through monitoring should be useful in evaluating past environmental treatments and in directing new treatments, management actions, and other human influences. The ultimate goal of environmental management is good stewardship. Monitoring should inform stewardship efforts and help us to protect and enhance the natural world.

The Systematic Approach

We have identified the following seven-step process for planning of environmental monitoring:

1. Prepare clear statements of the important Questions of Interest (QOI's).

2. Design the sampling systems.

3. Develop sampling protocols for data collection.

4. Prepare the data management systems.

5. Plan the analysis and interpretation systems.

6. Develop a reporting system.

7. Develop a monitoring sustainability plan.

Each of these seven steps must be undertaken and completed to develop a successful monitoring program. The steps must be undertaken in a comprehensive manner. Planning decisions made in any one stage affect decisions at all the other stages.

Each QOI, (described in the Compliance Monitoring and Effectiveness Monitoring sections of this Plan), has been quantified, prioritized, and evaluated in accord with the seven planning steps.

1. Prepare clear statements of the QOI's.

The first step in developing this Monitoring Plan required clearly defining the QOI's. Key questions are those with answers that can be efficiently estimated and that yield the information necessary for management decision-making. The Monitoring Program depends upon identification of the important issues and concerns, and reducing general problems to questions of specific, measurable factors. Much future effort will be spent investigating the QOI's. Among those will be compliance checks to ensure that mitigation guidelines are followed. The QOI's also include measurement of Wēkiu bug population changes and changes in habitat characteristics, to be examined for relationships to natural phenomena (weather/climate) and human activities at the summit.

2. Design the sampling systems.

The second step in developing this Monitoring Plan was designing the sampling systems. Proposed questions of interest were prioritized, based on the projected costs of collecting the data and the projected value of the knowledge to be gained. Expertise in statistics, biometrics, and cost / benefit analysis was required for sampling system design. Some of the design techniques that were applied are power analysis, cost allocation analysis, sampling structure determinations, sample size determinations, scale evaluations, randomization, replication, blocking, and covariate determinations. Schedules of sampling efforts were also developed. Monitoring is the investigation of change over time, so planning the frequency and timing of sampling was an essential element in the sampling system design.

3. Develop sampling protocols for data collection.

The third step in developing this Monitoring Plan was creating the data collection systems. Sampling protocols are necessary to standardize data collection. Data gathered in the future must be comparable to data gathered today to statistically detect significant environmental changes. The protocols include specific methods to be used for each QOI, descriptions of the tools necessary for data collection, and randomization schemes for determining trap placement or measurement device location. Some of these protocols have been field-tested to assure feasibility and efficiency. Nondestructive sampling techniques have been recommended.

4. Prepare the data management systems.

The fourth step in developing this Monitoring Plan was the preparation of a data management plan. The data collected in each sampling exercise will be checked for errors and corrected. Data sets will be entered into a database for easy access and retrieval. Monitoring requires comparisons of attributes over lengthy periods of time. The database must be properly archived to be retrievable many years in the future.

It is important to recognize that data sets are expensive to obtain, and hence have significant monetary value. Not only will the archived data contribute information for future management decisions in the vicinity of Pu'u Hau Oki, they will also provide information potentially useful for natural resource management elsewhere on the Mauna Kea summit and on other mountaintops in Hawai'i.

5. Plan the analysis and interpretation systems.

The fifth step in developing this Monitoring Plan was the development of an analysis and interpretation plan. Statistical analysis and scientific interpretation are necessary to produce logical inferences and new knowledge from monitoring data. Techniques of exploratory data analysis (EDA), graphics, statistical distribution tests, data transformations, and modeling are described in this Plan.

Much of the information gained through monitoring will be evaluated by means of mathematical models. Such models include time trend analysis, survival analysis, growth and mortality models, and population change models. The appropriate model forms are specified for each QOI. These include the environmental parameters to be estimated, inferential strength measures appropriate to each QOI, and methods of biological interpretation.

6. Develop a reporting system.

The sixth step in developing this Monitoring Plan was the development of a plan for reporting the results. The new knowledge acquired through monitoring will be communicated to responsible parties and agencies, including JPL, NASA, CARA, the IfA, and other groups. Charts, tables, and maps may be the immediate products of analysis, but they will not stand alone. Associated reports will be clearly written, with consideration of the intended audience and the appropriate application of the findings. The reports will clearly explain the results of data analysis and the implications to natural resource management. Monitoring

reports will be produced according to the schedules specified for each QOI.

7. Develop a monitoring sustainability plan.

The seventh step in developing this Monitoring Plan is consideration of monitoring sustainability. Institutional commitment from stakeholders must be developed to secure annual budgetary planning for future monitoring efforts. Monitoring happens in the context of time. Environmental changes, and trends in those changes, are often detected only after several years of data collection. The individuals, groups and agencies concerned with management of the Mauna Kea summit must consider the Monitoring Program to be a permanent fixture in future budgets. Involving other stakeholders, such as the Hawai'i Department of Land and Natural Resources, the US Fish and Wildlife Service, native Hawaiian groups, environmental groups, and concerned citizens will help to build community commitment to the program.

Figure 1 - 2. Mauna Kea summit in winter. *Photo by D.A. Swanson, courtesy US Geological Survey.*

COMPLIANCE MONITORING

2.1 - INTRODUCTION

Compliance monitoring studies the extent to which contractors, operators, managers, and visitors comply with Wēkiu bug protection guidelines and rules. This Compliance Monitoring section is based on the twenty Recommendations made in the Wēkiu Bug Mitigation Report (under separate cover). CARA developed the Wēkiu Bug Mitigation Report based on this report and the Recommendations contained therein. Monitoring for compliance with guidelines will give the operators, oversight agencies, and the public the information necessary to ensure that natural resources are protected during the Outrigger Telescopes project.

This Compliance Monitoring Section is organized into eight modules:

2.1 Introduction
2.1 Listing of QOI's
2.3 Habitat Restoration Module
2.4 Slope Stability Module
2.5 Dust Module
2.6 Hazardous Materials Module
2.7 Trash Module
2.8 Alien Arthropods Module

More Questions of Interest (QOI's) may be added, or some deleted, if and when desired. The Monitoring Program is thus adaptable to new conditions and findings.

Each Module contains a comprehensive discussion of each of the associated QOI's, including justification, monitoring goals, sampling systems, sampling protocols, analysis and interpretation, and reporting.

Subsections on data analysis, data management and reports may be found in Section 4 – Results. Reports called for in this Monitoring Plan include Quarterly Reports during construction, a synthesis report upon Construction Completion, and a Post-Construction Report one year following completion. Special reports for some QOI's are also planned. The more complex sampling protocols may be found in Section 6 - Protocols.

Many of the QOI's include the general question of "when". It should be noted that, for the purposes of this Monitoring Program, initial conditions are those that will be found when the first inventories are performed, not the conditions estimated or hypothesized to have existed prior to this project.

2.2 - LISTING OF THE COMPLIANCE MONITORING QUESTIONS OF INTEREST

2.3 - Habitat Restoration Module

2.3.1 What type of habitat restoration has occurred, (final designs, installation procedures followed), where has habitat been restored, (location, dimension), and when, (dates, progress)?

2.4 - Slope Stability Module

2.4.1 What kind of temporary and permanent barriers have been installed to prevent disturbance to Wēkiu bug habitat in Pu‘u Hau Oki crater, (final designs, installation procedures followed), where have they been installed (location, dimension), and when were they installed (dates, progress)?

2.4.2 Where, when, and in what quantities has cinder been accidentally side-cast into Wēkiu bug habitat in Pu‘u Hau Oki crater?

2.4.3. Where, when, and in what quantities has snow or ice (accumulated by plowing) been side-cast into Wēkiu bug habitat in Pu‘u Hau Oki crater?

2.4.4 Where, when, what kind, and how many educational signs, (placed to discourage pedestrian traffic in Wēkiu bug habitat in Pu‘u Hau Oki crater), have been installed?

2.5 - Dust Module

2.5.1 Where, when, and in what quantities has water been applied to excavation sites and cinder stockpiles created by earthmoving activities?

2.5.2 Where and when have dust-generating activities been suspended, (to prevent dust from being blown into Wēkiu bug habitat in Pu‘u Hau Oki crater)?

2.5.3 Where and when have excavated materials and cinder stockpiles been covered, (to prevent dust from being blown into Wēkiu bug habitat in Pu‘u Hau Oki crater)?

2.5.4 Where, when, and in what quantities have soil-binding compounds been used?

2.6 - Hazardous Materials Module

2.6.1 Where, when, and in what quantities have chemicals been used for washing observatory mirrors? Have all regulatory guidelines been followed, including the proper disposal of associated compounds, tools, and containers?

2.6.2 Where, when, and in what quantities have contractors used paints, thinners, and solvents on-site? Have all regulatory guidelines been followed, including the proper disposal of associated compounds, tools, and containers?

2.6.3 Where, when, and in what quantities have spills of hazardous materials occurred? In the case of spills, have all regulatory guidelines for spill cleanup been followed?

2.7 - Trash Module

2.7.1 Where and when have roll-off trash containers been tightly covered, (or uncovered)?

2.7.2 Where and when have construction materials stored at the site been covered with tarps, or anchored in place to prevent movement by wind (or left uncovered and/or unsecured)?

2.7.3 What kind of outdoor trash receptacles have been installed to prevent trash from being blown into Wēkiu bug habitat in Puʻu Hau Oki crater, where have they been installed, and when were they installed?

2.7.4 Where, when, what kind, and in what quantities have construction materials and other trash been blown into Wēkiu bug habitat in Puʻu Hau Oki crater? Where, when, and what methods have been used to collect construction materials and other trash blown into Wēkiu bug habitat in Puʻu Hau Oki crater?

2.8 - Alien Arthropod Module

2.8.1 Where and when have ants been detected at storage yards and staging areas, and what eradication actions have been taken?

2.8.2 Where and when have alien arthropods, or soil, dirt, or vegetation capable of harboring alien arthropods, been found on earth-moving equipment? When has earth-moving equipment been pressured-washed (to remove alien arthropods) before being moved to the construction site?

2.8.3 Where and when have large trucks, tractors, other vehicles, and construction materials been inspected before being transported to the summit? Have any alien arthropods been found in those inspections? Where, when, and what actions have been taken to eradicate any alien arthropods found in those inspections?

2.8.4 Where and when have shipping crates and boxes been inspected for spider webs, egg masses, and other signs of alien arthropods before being transported to the summit? Have any alien arthropods been found in those inspections? Where, when, and what actions have been taken to eradicate any alien arthropods found in those inspections?

2.8.5 Where, when, and in what quantities have alien arthropods been found at the WKMO observatory site? Where, when, and what actions have been taken to eradicate any alien arthropods found in those inspections?

2.3 - Habitat Restoration Module

Question of Interest 2.3.1

What type of habitat restoration has occurred, (final designs, installation procedures followed), where has habitat been restored, (location, dimension), and when, (dates, progress)?

Justification:

Habitat restoration areas will provide new habitat for Wēkiu bugs in areas damaged or disturbed by new or prior observatory construction activities, (see Recommendations IV-1 and IV-2 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To provide an historical record of Wēkiu Bug habitat restoration activities. See also Effectiveness Monitoring, Habitat, and Population.

Sampling System:

Sampling Measurements

2.3.1A) Professional review of plans prior to installation of the restored habitat. Engineers and entomologists will review proposed locations, designs, and construction procedures to insure that the restoration will have a high likelihood of recreating and restoring favorable Wēkiu bug habitat.

2.3.1B) Measurements during construction of restored areas.

1) Size distribution of screened and washed cinder used.
2) Locations, including spatial extent of site preparation and installation activities, as well as final size of restored areas.

2.3.1C) Measurements following construction of the restored areas.

1) Depths of installed screened and washed cinder.
2) Porosity of installed screened and washed cinder. Note: porosity is the percentage, by volume, of voids divided by the total volume of materials installed.

Sampling Intensities

2.3.1A) 100% review

2.3.1B1) Prior to installation count the number of rocks or rock fragments by diameter class (screen size) from a random sample of the screened and washed cinder to be used for habitat restoration. One twentieth of one percent (0.05%) of the material will be measured, (1 cubic foot measured per 2,000 cubic feet of screened and washed cinder). If screening and washing procedures are altered during construction, additional measurements should be made. Sampling target: 10 samples, 0.5 cu. ft. each.

2.3.1B2) After installation locate perimeter points every 20 feet around the restored areas. Locations should be accurate to ± 2 feet relative to fixed reference points, such as existing building corners or survey monuments. Sampling target: 15-20 located perimeter points, suitable for mapping the areas.

2.3.1C1) Measure depth of installed cinder ± 1 inch on a randomly located 20'x20' grid, (one measurement per 400 square feet of installed habitat mitigation structures or restored areas). Sampling target: 10 cinder depth measurements.

2.3.1C2) Measure porosity of installed screened and washed cinder. One twentieth of one percent (0.05%) of the installed material will be measured, (1 cubic foot measured per 2,000 cubic feet of screened and washed cinder). Sampling target: 10 samples, 1 cu. ft. each.

Sampling Frequencies

2.3.1A) Once, prior to restored habitat installation.

2.3.1B all) Once, during restored habitat installation. If procedures or locations are altered during installation, or repeated in new locations, measurements B1, B2, and B3 may need to be repeated.

2.3.1C all) Once, immediately after installation. If procedures or locations are altered during installation, or repeated in new locations, measurements C1, and C2 may need to be repeated.

Sampling Protocol: See Protocols, Habitat

Data Management: See Results, Data Management

Analysis and Interpretation:

2.3.1B1) Histogram

2.3.1B2) Map (GIS)

2.3.1C1) Mean, range, variation. Map point measurements (GIS)

2.3.1C2) Mean, range, variation. Map point measurements (GIS)

Reporting:

2.3.1A) Written review of habitat restoration plans, delivery prior to initiating installation.

2.3.1B all) Written report, within two months after installation.

2.3.1C all) Written report, within two months after installation. Include in Post Construction Report.

2.4 - SLOPE STABILITY MODULE

Question of Interest 2.4.1

What kind of temporary and permanent barriers have been installed to prevent disturbance to Wēkiu bug habitat in Pu'u Hau Oki crater, (final designs, installation procedures followed), where have they been installed (location, dimension), and when were they installed (dates, progress)?

Justification:

Temporary and permanent barriers constructed along the slope break prior to construction will prevent excavated cinder, construction materials, and trash from falling or blowing into Pu'u Hau Oki crater, (see Recommendation IV-3 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To provide an historical record of Wēkiu bug habitat protection activities. See also Effectiveness Monitoring, Habitat Structure Module.

Sampling System:

Sampling Measurements

2.4.1A) Measurements during construction and use of temporary barriers.
- **1)** Sizes, shapes, colors, and face textures of any barriers used.
- **2)** Locations of any barriers used.

2.4.1B) Measurements after installation of permanent barriers.
- **1)** Sizes, shapes, colors, and face textures of any barriers used.
- **2)** Locations of any barriers used.

Sampling Intensities

2.4.1A1 & 2.4.1B1) Describe each type of barrier used.

2.4.1A2 & 2.4.1B2) Locate points every 20 feet along the barriers. Locations should be accurate to ± 1 foot relative to fixed reference points, such as existing building corners or survey monuments. Sampling target: 20 located barrier points, suitable for mapping the barriers.

Sampling Frequencies

2.4.1 all) Once for each type of barrier. In addition, compliance visual inspections at random intervals, averaging once per month.

Sampling Protocol:

2.4.1A2 & 2.4.1B2) Tools: 100′ tape measure, compass, clinometer
Procedures: measure distance, azimuth, and slope from fixed reference points to points every 20′ along the temporary and permanent barriers.

Data Management: See Results, Data Management

Analysis and Interpretation:

2.4.1A1 & 2.4.1B1) Description

2.4.1A2 & 2.4.1B2) Map (GIS)

Reporting:

2.4.1A1& 2.4.1A2) For temporary barriers, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

2.4.1B1 & 2.4.1B2) For permanent barriers, a written report, within two months after installation. Include in Post Construction Report.

Question of Interest 2.4.2

Where, when, and in what quantities has cinder been accidentally side-cast into Wēkiu bug habitat in Pu'u Hau Oki crater?

Justification:

Excavated cinder, side cast into Wēkiu bug habitat, could alter slope stability and habitat structure. (see Recommendation IV-3 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To detect hazards and risks to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities. See also Effectiveness Monitoring, Habitat Structure Module.

Sampling System:

Sampling Measurements

2.4.2A) Measure, during construction, the change in cinder surface position down slope of the construction areas adjacent to Pu'u Hau Oki crater.

Sampling Intensities

2.4.2A) Measurement points every 20 feet horizontally (on the contour) 10 feet (slope distance) down slope of construction areas for Outrigger Telescopes 1 and 2 (on the Pu'u Hau Oki crater side). Sampling target: 15-20 located measurement points.

Sampling Frequencies

2.4.2A) Once per month during construction, and again one year following completion of construction activities. Sampling target: 18-21 dates.

Sampling Protocol:

2.4.2A) Tools: Prepare measuring rods, using 6-foot-long rebar or metal fence posts, by painting white with red or black marks at one inch increments from top.

Procedures: Locate and mark with survey stakes the boundaries of construction areas. Drive measuring rods securely into the slope every 20 feet on the contour, 10 feet slope distance below edge of construction areas for Outrigger Telescopes 1 & 2 (on the Pu'u Hau Oki crater side). Repair and restore (by raking) the slope surface around each measuring rod. Record the vertical distance (length in inches) from the surface to the top of each measuring rod. Subsequent measurements should be made using binoculars to view the rods from upslope positions (to minimize any further habitat disturbance). Repeat these measurements once per month. If significant amounts of side cast cinder are detected, estimate the slope distance (in feet, down slope of each measuring rod, that side cast cinder is visually evident.

Data Management: See Results, Data Management

Analysis and Interpretation Systems:

2.4.2A) If the measuring rods are driven securely, they should not move up or down. If significant amounts of cinder are side cast from construction activities, changes in the vertical distances from the surface to the top of each rod will be detected. Trigonometric calculations, using the estimated down slope coverage of side cast cinder, will yield volume estimates of the amount of cinder side cast into Wēkiu bug habitat in Pu'u Hau Oki crater. Repeating the measurements every two weeks will provide an ongoing assessment of side cast cinder.

Reporting System:

2.4.2A) If side cast cinder is detected, it should be reported immediately. Otherwise, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.4.3

Where, when, and in what quantities has snow or ice (accumulated by plowing) been side-cast into Wēkiu bug habitat in Pu'u Hau Oki crater?

Justification:

Large quantities of accumulated snow (ice boulders), side cast into Wēkiu bug habitat, could alter slope stability and habitat structure, (see Recommendation IV-3 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To detect hazards and risks to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities. See also Effectiveness Monitoring, Habitat Structure Module.

Sampling System:

Sampling Measurements

2.4.3A) Measure snow accumulations, should they occur, along the upper edge of Pu'u Hau Oki crater.

Sampling Intensities

2.4.3A) Measurement points every 40 feet horizontally along the upper edge of Pu'u Hau Oki crater. Sampling target: 10 located measurement points.

Sampling Frequencies

2.4.3A) Once per month, during periods when snow accumulates (from plowing or other snow removal methods). It is possible that deep snow may not occur during the Outrigger Telescope project.

Sampling Protocol:

2.4.3A) Tools: 100′ tape measure, shovel

Procedures: Measure width, breadth, and length of snow accumulations at points every 40′ along the upper edge of Puʻu Hau Oki crater.

Data Management: See Results. Data Management

Analysis and Interpretation Systems:

2.4.3A) Time series, volume of accumulated snow at dates.

Reporting System:

2.4.3A) If conditions are found that constitute a hazard to Wēkiu bug habitat in Puʻu Hau Oki crater, it should be reported immediately. Otherwise, include in Quarterly Reports, Construction Completion Report within two months after the completion of construction activities, and in the Post-Construction Report.

Question of Interest 2.4.4

Where, when, what kind, and how many educational signs, (placed to discourage pedestrian traffic in Wēkiu bug habitat in Pu'u Hau Oki crater), have been installed?

Justification:

Educational signs will help prevent unintentional disturbance of Wēkiu bug habitat by workers and visitors, (see Recommendation IV-4 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To provide an historical record of Wēkiu bug habitat protection activities. See also Effectiveness Monitoring, Habitat Structure Module.

Sampling System:

Sampling Measurements

2.4.4A) Measurements following installation
- **1)** Sizes, shapes, colors, and content of any educational signs used
- **2)** Locations of any educational signs used

Sampling Intensities

2.4.4A all) Describe each type of educational signs used and their locations. Locations should be accurate to ± 1 foot relative to fixed reference points, such as existing building corners or survey monuments.

Sampling Frequencies

2.4.4A all) Once, following sign installation.

Sampling Protocol:

2.4.4A all) **Tools:** 100′ tape measure, camera

Procedures: Measure distance, azimuth, and slope from fixed reference points to each educational sign. Photograph sign for record of content.

Data Management: See Data Management, Results Section

Analysis and Interpretation Systems:

2.4.4A all) Descriptions with photographs

Reporting System:

2.4.4A all) A written report within two months of completion of installation of educational signs, and include in the Construction Completion and Post-Construction Reports.

2.5 - DUST MODULE

Question of Interest 2.5.1

When and in what quantity has water been applied to excavation sites and cinder stockpiles created by earthmoving activities?

Justification:

Excessive deposition of ash and dust from excavation activity may alter the structure of Wēkiu bug habitat in Puʻu Hau Oki crater, (see Recommendation V-1 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To provide an historical record of Wēkiu bug habitat protection activities. See also Effectiveness Monitoring, Habitat Structure Module.

Sampling System:

Sampling Measurements

2.5.1A) Measurements during construction

1) The number of excavations
2) The dates when water was applied to excavation sites and cinder stockpiles
3) The quantity and dates of water trucked to the construction site

Sampling Intensities

2.5.1A all) 100% review of Contractors' Log Book

Sampling Frequencies

2.5.1A all) Once per month, during construction.

Sampling Protocol: See Protocols, Contractors' Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.5.1A1) Time series, dates of excavation activity.

2.5.1A2) Time series, dates water was applied to excavation sites and cinder stockpiles.

2.5.1A3) Time series, quantity of water delivered at dates.

Reporting:

2.5.1A all) If water is not being used to suppress dust, it should be reported immediately. Otherwise, include in Quarterly Reports, and in the Construction Completion Report within two months after completion of construction activities.

Question of Interest 2.5.2

When have dust-generating activities been suspended, (to prevent dust from being blown into Wēkiu bug habitat in Pu'u Hau Oki crater)?

Justification:

High winds at the summit are capable of blowing dust from recently exposed cinder and ash onto habitat slopes. Excessive deposition of ash and dust from excavation activity may alter the structure of Wēkiu bug habitat in Pu'u Hau Oki crater, (see Recommendation V-2 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To provide an historical record of Wēkiu bug habitat protection activities, (see also Effectiveness Monitoring, Habitat Structure Module), and to associate auxiliary phenomena, attributes, and characteristics with trends and patterns of change in key phenomena, attributes, and characteristics.

Sampling System:

Sampling Measurements

2.5.2A) Measurements during construction
- **1)** Dates of suspension of dust-generating activities.
- **2)** Wind speed in miles per hour.

Sampling Intensities

2.5.2A1) 100% review of Contractors' Log Book.

2.5.2A2) Records from available meteorological information.

Sampling Frequencies

2.5.2A1) Once per month during the construction phase of the project.

2.5.2A2) As recorded by existing weather monitoring equipment.

Sampling Protocol: See Protocols, Contractors' Log Book and Meteorological Station

Data Management: See Results, Data Management

Analysis and Interpretation:

2.5.2A1) Time series, dates of suspension of dust-generating activities.

2.5.2A2) Time series daily high and lows. Comparison with suspension dates.

Reporting:

2.5.2A all) If dust-generating activities are not being suspended during periods of high winds, it should be reported immediately. Otherwise, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.5.3

Where and when have excavated materials and cinder stockpiles been covered, (to prevent dust from being blown into Wēkiu bug habitat in Pu'u Hau Oki crater)?

Justification:

High winds at the summit are capable of blowing dust from recently exposed cinder and ash onto habitat slopes. Excessive deposition of ash and dust from excavation activity may alter the structure of Wēkiu bug habitat in Pu'u Hau Oki crater, (see Recommendation V-2 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To provide an historical record of Wēkiu bug habitat protection activities, (see also Effectiveness Monitoring, Habitat Structure Module).

Sampling System:

Sampling Measurements

2.5.3A) Measurements during construction
- **1)** Dates excavated materials have been covered
- **2)** Wind speed in miles per hour.

Sampling Intensities

2.5.3A1) 100% review of Contractors' Log Book.

2.5.3A2) Records from available meteorological information.

Sampling Frequencies

2.5.3A1) Once per month during the construction phase of the project.

2.5.3A2) As recorded by existing weather monitoring equipment.

Sampling Protocol: See Protocols, Contractors' Log Book and Meteorological Station

Data Management: See Results, Data Management

Analysis and Interpretation:

2.5.3A1) Time series, dates excavated materials have been covered.

2.5.3A2) Time series daily high and lows. Comparison with covering dates.

Reporting:

2.5.3A all) If excavated materials and stockpiles are not being covered during periods of high winds, it should be reported immediately. Otherwise, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.5.4

Where, when, and in what quantities have soil-binding compounds been used?

Justification:

Application of soil-binding compounds may reduce dust created during excavation or generated from vehicle traffic. Soil-binding compounds should not be applied to Wēkiu Bug habitat, (see Recommendation V-3 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To provide an historical record of Wēkiu bug habitat protection activities. See also Effectiveness Monitoring, Habitat Structure Module.

Sampling System:

Sampling Measurements

2.5.4A) Professional review of soil-binding compounds prior to use at the construction site.

2.5.4B) Locations, dates, and quantities of soil-binding compounds applied.

Sampling Intensities

2.5.4A) Review of soil-binding compounds plans.

2.5.4B) 100% review of Contractors' Log Book.

Sampling Frequencies:

2.5.4A) Once, prior to application of soil-binding compounds.

2.5.4B) Once per month during the construction phase of the project.

Sampling Protocol: See Protocols, Contractors' Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.5.4B) Spatial time series: locations, dates, and quantities of soil-binding compounds.

Reporting:

2.5.4A) Written review of soil-binding compounds proposed for application, delivery prior to application.

2.5.4B) Include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

2.6 - HAZARDOUS MATERIALS MODULE

Question of Interest 2.6.1

Where, when, and in what quantities have chemicals been used for recoating observatory mirrors? Have all regulatory guidelines been followed, including the proper disposal of associated compounds, tools, and containers?

Justification:

When managed properly according to Federal guidelines, hazardous materials used during the mirror-washing procedures at WKMO pose little danger to the surrounding environment. Monitoring mirror-washing procedures provides assurance of safety, (see Recommendation VI-1 in the Wēkiu Bug Mitigation Report)

Monitoring Goals:

To detect threshold events, or critical levels, of environmental phenomena, attributes, and characteristics, and to provide an historical record of Wēkiu bug habitat protection activities.

Sampling System:

Sampling Measurements

2.6.1A) Measurements made during mirror washing activities
- **1)** Dates, locations, and quantities of chemicals used in mirror washing.
- **2)** Chemical and container disposal procedures followed.

Sampling Intensities

2.6.1A1 & 2.6.1A2) 100% review of procedural reports. CARA personnel currently report on procedures used in mirror washing, in accordance with Federal guidelines. CARA personnel will keep an Activity Log Book that will be available for review during monthly site inspections.

Sampling Frequencies

2.6.1A1 & 2.6.1A2) On dates when mirror washing occurs.

Sampling Protocol:

2.6.1A1) Monthly review of Activity Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.6.1A1) Time series, Dates, locations, and quantities of chemicals used in mirror washing activities.

2.6.1A2) Descriptive statistics of chemical and container disposal procedures.

Reporting:

2.6.1A1 & 2.6.1A2) Include in Quarterly Reports, and in the Post-Construction Report.

Question of Interest 2.6.2

Where, when, and in what quantities have contractors used paints, thinners, and solvents on-site? Have all regulatory guidelines been followed, including the proper disposal of associated compounds, tools, and containers?

Justification:

Paints, thinners and other solvents are toxic to Wēkiu bugs, and spills could impact Wēkiu bug populations. Monitoring the use of paints, thinners, and solvents on-site provides assurance of safety, (see Recommendation VI-2 in the Wēkiu Bug Mitigation Report)

Monitoring Goals:

To detect hazards and risks to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities.

Sampling System:

Sampling Measurements

2.6.2A) Review of Contractors' hazardous materials plans prior to use of paints, thinners, and solvents on-site.

2.6.2B) Locations, dates, and quantities of paints, thinners, and solvents used on-site, including equipment washing activities and disposal of chemicals and containers.

Sampling Intensities

2.6.2A) 100% review of Contractors' hazardous materials plans

2.6.2B) 100% review of Contractors' Log Book

Sampling Frequencies

2.6.2A) Once, prior to prior to use of paints, thinners, and solvents on-site.

2.6.2B) Once per month during the construction phase of the project.

Sampling Protocol: See Protocols, Contractors' Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.6.2B) Spatial time series: locations, dates, and quantities of paints, thinners, and solvents used on-site including equipment washing activities and disposal of chemicals and containers

Reporting:

2.6.2 all) If a spill occurs, or improper procedures are being used, it should be reported immediately. Otherwise, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.6.3

Where, when, and in what quantities have spills of hazardous materials occurred? In the case of spills, have all regulatory guidelines for spill cleanup been followed?

Justification:

If spilled onto Wēkiu bug habitat, paints, thinners, solvents, or other hazardous materials can impact Wēkiu bug populations. Should spills occur, monitoring of their impact and associated clean-up efforts is necessary, (see Recommendation VI-2 in the Wēkiu Bug Mitigation Report)

Monitoring Goals:

To detect hazards and risks to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities.

Sampling System:

Sampling Measurements

2.6.3A) Review of spill response sections of the Contractors' hazardous materials plans, prior to use of paints, thinners, and solvents on-site.

2.6.3B) Measurements during construction

1) Locations, dates, and quantities of spills, should they occur.

2) Locations, dates, and procedures followed in clean-up of spills, should they occur.

Sampling Intensities

2.6.3A) 100% review of Contractors' hazardous materials plans

2.6.3B1 & 2.6.3B2) 100% review of Contractors' Log Book

Sampling Frequencies

2.6.3A) Once, prior to prior to use of paints, thinners, and solvents on-site

2.6.3B1 & 2.6.3B2) Once per month during the construction phase of the project.

Sampling Protocol: See Protocols, Contractors' Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.6.3B1 & 2.6.3B2) Spatial time series: locations, dates, and quantities of spills and clean-up efforts.

Reporting:

2.6.3 all) In case of a spill, report immediately, with monthly follow-up reports on the spill extent and clean-up actions. If no spills occur, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

2.7 - TRASH MODULE

Question of Interest 2.7.1

Where and when have roll-off trash containers been tightly covered, (or uncovered)?

Justification:

High winds at the summit can extract construction debris from containers and disperse the material. Covering containers will decrease the amount of construction debris that could be blown onto Wēkiu bug habitat, (see Recommendation VII-1 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To detect hazards and risks to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities.

Sampling System:

Sampling Measurements

2.7.1A) Measurements during construction
- **1)** Locations and dates roll-off trash containers at construction site.
- **2)** Wind speed in miles per hour.

Sampling Intensities

2.7.1A1) 100% review of Contractors' Log Book

2.7.1A2) Records from available meteorological information.

Sampling Frequencies

2.7.1A1) Once per month during the construction phase of the project.

2.7.1A2) As recorded by existing weather monitoring equipment.

Sampling Protocol: See Protocols, Contractors' Log Book and Meteorological Station

Data Management: See Results, Data Management

Analysis and Interpretation:

2.7.1A1) Time series, Dates roll-off trash containers have been covered.

2.7.1A2) Time series daily high and lows. Comparison with covering dates.

Reporting:

2.7.1 all) If roll-off trash containers are not being covered during periods of high winds, it should be reported immediately. Otherwise, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.7.2

Where and when have construction materials stored at the site been covered with tarps, or anchored in place to prevent movement by wind (or left uncovered and/or unsecured)?

Justification:

High winds at the summit can potentially blow construction materials onto habitat slopes. Covering construction materials stored at the site will decrease the amount of construction debris that could be blown into Wēkiu bug habitat, (see Recommendation VII-2 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To detect hazards and risks to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities.

Sampling System:

Sampling Measurements

2.7.2A) Measurements during construction
- **1)** Locations and dates construction materials at construction site.
- **2)** Wind speed in miles per hour.

Sampling Intensities

2.7.2A1) 100% review of Contractors' Log Book

2.7.2A2) Records from available meteorological information.

Sampling Frequencies

2.7.2A1) Once per month during the construction phase of the project. I

2.7.2A2) As recorded by existing weather monitoring equipment.

Sampling Protocol: See Protocols, Contractors' Log Book and Meteorological Station

Data Management: See Results, Data Management

Analysis and Interpretation:

2.7.2A1) Time series, Dates construction materials have been covered.

2.7.2A2) Time series daily high and lows. Comparison with covering dates.

Reporting:

2.7.2 all) If construction materials are not being covered during periods of high winds, it should be reported immediately. Otherwise, include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.7.3

What kind of outdoor trash receptacles have been installed to prevent trash from being blown into Wēkiu bug habitat in Pu'u Hau Oki crater, where have they been installed, and when were they installed?

Justification:

Workers and visitors to the WKMO often bring trash, (lunch bags, film canisters, wrappers, etc.). Trash receptacles provide workers and visitors with a place to dispose of their trash and prevent it from being blown into Wēkiu bug habitat, (see Recommendation VII-3 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To detect hazards and risks, to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities.

Sampling System:

Sampling Measurements

2.7.3A) Measurements during construction
- **1)** Review of plans prior to construction and installation of trash receptacles.
- **2)** Locations and dates of installation of trash receptacles.

Sampling Intensities

2.7.3A1) 100% review of trash receptacle plans

2.7.3A2) 100% review of Contractors' Log Book

Sampling Frequencies

2.7.3A1) Once, prior to installation

2.7.3A2) Once, after installation.

Sampling Protocol: See Protocols, Contractors' Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.7.3A2) Descriptions of trash receptacles with dates of installation

Reporting:

2.7.3 all) Include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.7.4

Where, when, what kind, and in what quantities have construction materials and other trash been blown into Wēkiu bug habitat in Puʻu Hau Oki crater? Where, when, and what methods have been used to collect construction materials and other trash blown into Wēkiu bug habitat in Puʻu Hau Oki crater?

Justification:

Despite efforts to prevent wind-blown construction materials and trash, some debris could end up in Wēkiu bug habitat. Retrieving this debris from sensitive areas should be done without disturbing the habitat, (see Recommendation VII-4 in the Wēkiu Bug Mitigation Report).

Monitoring Goals:

To detect hazards and risks, to valued ecosystem attributes and functions, and to provide an historical record of Wēkiu bug habitat protection activities.

Sampling System:

Sampling Measurements

2.7.4A) Measurements during construction

1) Review of plans prior to collection of debris from Wēkiu bug habitat in Puʻu Hau Oki crater.
2) Locations and dates of trash collection.

Sampling Intensities

2.7.4A1) 100% review of trash collection plans

2.7.4A2) 100% review of Contractors' Log Book

Sampling Frequencies

2.7.4A1) Once

2.7.4A2) Once per month during the construction phase of the project.

Sampling Protocol: See Protocols, Contractors' Log Book

Analysis and Interpretation:

2.7.4A2) Descriptions of trash collection activities, with dates and locations

Reporting:

2.7.4 all) Include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

2.8 - ALIEN ARTHROPODS MODULE

Question of Interest 2.8.1

Where and when have ants been detected at storage yards and staging areas, and what eradication actions have been taken?

Justification:

Ants in storage yards and staging areas may be accidentally transported to the construction site. Several species of ants have established populations on the Island that could pose a threat to Wēkiu bugs. Efforts must be made to ensure that ants are not transported to the summit, (see Recommendation VIII-1 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To detect hazards and risks to Wēkiu bugs, and to provide an historical record of Wēkiu Bug habitat protection activities.

Sampling System:

Sampling Measurements

2.8.1A) Measurements at storage yards and staging areas within the MKSR
- **1)** Presence/absence of ants on the ground
- **2)** Presence/absence of ants on vehicles
- **3)** Review of ant eradication plans
- **4)** Actions taken to eradicate ants

Sampling Intensities:

2.8.1A1) Place baited ant traps on a randomly located 40'x40' grid, (one measurement per 1600 square feet). Sampling target 25 traps per storage yard or staging area.

2.8.1A2) All vehicles at storage yard or staging area at time of inspection.

2.8.1A3) 100% review of ant eradication plans

2.8.1A4) 100% review of Contractors' Log Book

Sampling Frequencies:

2.8.1A1, 2.8.1A2, & 2.8.1A4) Once per month during the construction phase of the project.

2.8.1A3) Once, prior to initiation of ant eradication activities

Sampling Protocol:

2.8.1A1) Locate random sampling points (See Protocols, Habitat) and set freshly baited traps. Return after 3 hours and record presence/absence of ants.

2.8.1A2) See Protocols, Alien Arthropod Inspection

2.8.1A4) Review Contractors' Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.8.1A1 & 2.8.1A2) Time series, presence/absence of ants on dates.

2.8.1A4) Description

Reporting:

2.8.1A all) If ants are found at storage yards or staging areas within the MKSR, it should be reported immediately. Otherwise include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.8.2

Where and when have alien arthropods, or soil, dirt, or vegetation capable of harboring alien arthropods, been found on earth-moving equipment? When has earth-moving equipment been pressured-washed (to remove alien arthropods) before being moved to the construction site?

Justification:

Mud and dirt attached to earth-moving equipment should be removed before transport to the summit, where alien arthropods may pose a threat to Wēkiu bugs, (see Recommendation VIII-1 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To detect hazards and risks to Wēkiu bugs, and to provide an historical record of Wēkiu Bug habitat protection activities.

Sampling System:

Sampling Measurements

2.8.2A) Measurements taken during construction
- **1)** Presence/absence of alien arthropods on earth-moving equipment.
- **2)** Presence/absence of soil, dirt, and vegetation on earth-moving equipment.

2.8.2B) Information from contractors and subcontractors
- **1)** Date and description of most recent pressure washing of vehicles and earth-moving equipment used at the construction site.

Sampling Intensities:

2.8.2A1 & 2.8.2A2) All earth-moving equipment at construction site, or MKSR storage yards or staging areas, at time of inspection

2.8.2B1) 100% review of Contractors' Log Book

Sampling Frequencies:

2.8.2A1 & 2.8.2A2) Once per month during the construction phase of the project.

2.8.2B1) Once for each earth-moving equipment contractor and subcontractor

Sampling Protocol:

2.8.2A1 & 2.8.2A2) See Protocols, Alien Arthropod Inspection

2.8.2B1) Review Contractors' Log Book

Data Management: See Results, Data Management

Analysis and Interpretation:

2.8.2A1 & 2.8.2A2) Time series, number of vehicles with alien arthropods, soil, dirt, or vegetation at dates.

2.8.2B1) Description

Reporting:

2.8.2A1 & 2.8.2A2) If alien arthropods are found on earth-moving equipment, or if soil, dirt, or vegetation is found on earth-moving equipment at the construction site, it should be reported immediately. Otherwise include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

2.8.2B1) Include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.8.3

Where and when have large trucks, tractors, other vehicles, and construction materials been inspected before being transported to the summit? Have any alien arthropods been found in those inspections? What actions have been taken to eradicate any alien arthropods found in those inspections?

Justification:

Large trucks, tractors, other vehicles, and construction materials should be inspected before transport to the summit, where alien arthropods may pose a threat to Wēkiu bugs, (see Recommendation VIII-2 in the Wēkiu Bug Mitigation Report).

Monitoring goals:

To detect hazards and risks to Wēkiu bugs, and to provide an historical record of Wēkiu Bug habitat protection activities.

Sampling System:

Sampling Measurements

2.8.3A) Information obtained from operators of large trucks, tractors, other vehicles, and construction materials (see Protocols, Contractors' Log Book).

1) Inspections conducted for alien arthropods.
2) Actions taken to remove alien arthropods.

Sampling Intensities:

2.8.3A1 & 2.8.3A2) 100% review of Contractors' Log Book

Sampling Frequencies:

2.8.3A1 & 2.8.3A2) Once per month during the construction phase of the project, consisting of visual inspections of large trucks, tractors, other vehicles, and construction materials at the site during the inspection visit.

Sampling Protocol:

2.8.3A1 & 2.8.3A2) See Protocols, Contractors' Log Book and Alien Arthropod Inspection

Data Management: See Results, Data Management

Analysis and Interpretation:

2.8.3A1) Time series, number of large trucks, tractors, other vehicles, and construction materials found with alien arthropods at dates.

2.8.3A2) Description

Reporting:

2.8.3A1 & 2.8.3A2) If alien arthropods are found on large trucks, tractors, other vehicles, and construction materials at the construction site, it should be reported immediately. Otherwise include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.8.4

When have shipping crates and boxes been inspected for spider webs, egg masses, and other signs of alien arthropods before being transported to the summit? Have any alien arthropods been found in those inspections? What actions have been taken to eradicate any alien arthropods found in those inspections?

Justification:

Inspection and removal of alien arthropods will reduce the chance that these species will establish populations in Wēkiu bug habitat in Pu'u Hau Oki crater, (Wēkiu Bug Mitigation Report recommendation VIII-2).

Monitoring goals:

To detect hazards and risks to Wēkiu bugs, and to provide an historical record of Wēkiu Bug habitat protection activities.

Sampling System:

Sampling Measurements

2.8.4A) Information obtained from Contractors' Log Book (see Protocols, Contractors' Log Book and Alien Arthropod Inspection).

1) Inspections conducted for alien arthropods.
2) Actions taken to remove alien arthropods.

Sampling Intensities:

2.8.4A1 & 2.8.4A2) 100 % review of Contractors' Log Book

Sampling Frequencies:

2.8.4A1 & 2.8.4A2) Once per month during the construction phase of the project.

Sampling Protocol:

2.8.4A1 & 2.8.4A2) See Protocols, Contractors' Log Book and Alien Arthropod Inspection.

Data Management: See Results, Data Management

Analysis and Interpretation:

2.8.4A1) Time series, number of shipping crates and boxes found with alien arthropods at dates.

2.8.4A2) Description

Reporting:

2.8.4A1 & 2.8.4A2) If alien arthropods found on shipping crates and boxes, it should be reported immediately. Otherwise include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

Question of Interest 2.8.5

Where, when, and in what quantities have alien arthropods been found at the WKMO observatory site? Where, when, and what actions have been taken to eradicate any alien arthropods found in those inspections?

Justification:

Monitoring for of visible signs of alien arthropods, and eradicating alien arthropods if detected, will reduce the chance of these species from establishing populations will establish populations in Wēkiu bug habitat in Pu'u Hau Oki crater, (Wēkiu Bug Mitigation Report recommendation VIII-4).

Monitoring goals:

To detect hazards and risks to Wēkiu bugs, and to provide an historical record of Wēkiu Bug habitat protection activities.

Sampling System:

Sampling Measurements

2.8.5A) Measurements of alien arthropods

1) Presence/absence of ants.
2) Presence/absence spider webs on buildings, trailers, other observatory structures, and/or construction materials stored at the construction site.
3) Presence/absence of yellowjackets.

2.8.5B) Quantitative description of actions taken to eradicate any alien arthropods found during inspections.

Sampling Intensities:

2.8.5A1) Place baited ant traps on the ground next to temporary and permanent buildings at 40-foot intervals, at 20-foot intervals around construction materials stored at the construction site.

2.8.5A2) Visual inspection of temporary and permanent buildings, trailers other observatory structures, and construction materials stored at the construction site. See Protocols, Alien Arthropod Inspection.

2.8.5A3) Place 10 yellowjacket traps around the construction site, including locations near trash containers and portable toilets.

2.8.5B) Descriptions of actions taken, if and when they are taken.

Sampling Frequencies:

2.8.5A all) Once per month during the construction phase of the project.

2.8.5B) Descriptions of actions taken, if and when they are taken.

Sampling Protocol:

2.8.5A1) Locate sampling points and set freshly baited traps. Return after 3 hours and record number of ants at the trap.

2.8.5A2) See Protocols, Alien Arthropod Inspection

2.8.5A3) Locate sampling points and set freshly baited traps. Return after 3 hours and record number of yellowjackets in the traps.

2.8.5B) Quantitative descriptions of actions taken, if and when they are taken, including dates, locations, control methods applied, control method applicators, etc.

Data Management: See Results, Data Management

Analysis and Interpretation:

2.8.5A1) Spatial time series, number of traps that captured ants at dates and locations.

2.8.5A2) Spatial time series, number of spider webs at dates and locations.

2.8.5A3) Spatial time series, number of traps that captured yellowjackets at dates and locations.

2.8.5B) Quantitative description. Compare pre- and post-control-action trap counts.

Reporting:

2.8.5A all) If alien arthropods are found at the observatory site, it should be reported immediately. Otherwise include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

2.8.5A4) Actions taken to eradicate alien arthropods found at the observatory site should be reported monthly. Otherwise include in Quarterly Reports, and in the Construction Completion Report within two months after the completion of construction activities.

EFFECTIVENESS MONITORING

3.1 - INTRODUCTION

Effectiveness monitoring will investigate the changes in the Wēkiu bug population and habitat that happen concurrently with construction and operation of the Outrigger Telescopes. In essence, effectiveness monitoring asks whether the environmental controls adopted and mitigation treatments undertaken were successful in conserving the Wēkiu bug. Monitoring for changes in the population and habitat will give the operators, oversight agencies, and the public the information necessary to ensure that natural resources are protected during the Outrigger Telescope project.

This Effectiveness Monitoring Section is organized in four modules:

3.1 Introduction
3.2 Listing of the Questions of Interest
3.3 Population Change Module
3.4 Habitat Structure Module

More Questions of Interest (QOI's) may be added, or some deleted, if and when necessary. The Monitoring Program is thus adaptable to new conditions and findings.

Each Module contains a comprehensive discussion of each of the associated QOI's, including justification, monitoring goals, sampling systems, sampling protocols, analysis and interpretation, and reporting.

Subsections on data management, analysis, and reporting may be found in Section 4 – Results. Reports called for in this Monitoring Plan include Quarterly Reports during construction, a synthesis report upon Construction Completion, and a Post-Construction Report one year following completion. Special reports for some QOI's are also planned.

3.2 - LISTING OF THE EFFECTIVENESS MONITORING QUESTIONS OF INTEREST

3.3 - Population Change Module

3.3.1 How, where and when are the Wēkiu bug and other resident arthropod populations changing? Locations of interest include newly restored Wēkiu bug habitat, current habitat in Pu'u Hau Oki crater, and undisturbed Wēkiu bug habitat in other Mauna Kea summit areas (for comparison).

3.3.2 Are weather phenomena, human activities, and/or other factors associated with Wēkiu bug and/or other resident arthropod population change?

3.4 - Habitat Structure Module

3.4.1 How, where and when has existing Wēkiu bug habitat been damaged by new construction?

3.3 - POPULATION CHANGE MODULE

Question of Interest 3.3.1

How, where and when are the Wēkiu bug and other resident arthropod populations changing? Locations of interest include newly restored Wēkiu bug habitat, current habitat in Puʻu Hau Oki crater, and undisturbed Wēkiu bug habitat in other Mauna Kea summit areas (for comparison).

Justification:

Monitoring both the Wēkiu bug population and resident arthropod populations will yield reliable scientific information about population change, and whether mitigation and habitat restoration efforts have been successful at protecting and enhancing Wēkiu bugs and their habitat.

Monitoring goals:

1) To provide historical records of change in environmental phenomena, attributes, and characteristics,

2) To detect trends, periodicities, cycles, and/or other patterns in those changes, and

3) To associate auxiliary phenomena, attributes, and characteristics with trends and patterns of change in key phenomena, attributes, and characteristics

Sampling System:

Sampling Measurements

3.3.1A) Wēkiu bug population measurements
- **1)** in restored habitat
- **2)** in Puʻu Hau Oki crater
- **3)** in undisturbed Wēkiu bug habitat in other Mauna Kea summit areas

3.3.1B) Resident arthropod population measurements

1) in restored habitat
2) in Puʻu Hau ʻOki crater
3) in undisturbed Wēkiu bug habitat in Puʻu Wēkiu

Sampling Intensities

3.3.1A1 and 3.3.1B1) 3 pitfall traps in restored habitat

3.3.1A2 and 3.3.1B2) 5 pitfall traps in current habitat in Puʻu Hau ʻOki crater

3.3.1A3 and 3.3.1B3) 5 pitfall traps in undisturbed Wēkiu bug habitat in Puʻu Wēkiu.

Sampling Frequencies

3.3.1A all and 3.3.1B all) 21 day trapping sessions, four times per year (late winter, spring, summer, late fall).

Sampling Protocol: See Protocols, Population

Data Management: See Results, Data Management

Analysis and Interpretation:

3.3.1A all and 3.3.1B all) Spatial time series, capture rates at dates and locations, comparison with undisturbed sites. Include auxiliary weather data (QOI 3.3.2, this Module) in analyses.

Reporting:

3.3.1A all and 3.3.1B all) Include in Quarterly Reports, Construction Completion Report within two months after the completion of construction activities, and in the Post-Construction Report.

Question of Interest 3.3.2

Are weather phenomena, human activities, and/or other factors associated with Wēkiu bug and/or other resident arthropod population change?

Justification:

Snow, rain, day/night temperatures, and other weather phenomena may be associated with Wēkiu Bug population change. Human activities such as dust generation, side cast of debris on to habitat slopes, or other activities, and the presence/absence of alien arthropods may also be associated with population change. Monitoring these indirect factors will aid in analysis of mitigation success.

Monitoring goals:

1) To provide historical records of change in environmental phenomena, attributes, and characteristics,

2) To detect trends, periodicities, cycles, and/or other patterns in those changes, and

3) To associate auxiliary phenomena, attributes, and characteristics with trends and patterns of change in key phenomena, attributes, and characteristics

Sampling System:

Sampling Measurements

3.3.2A) Desirable meteorological measurements

1. **1)** Temperature
2. **2)** Wind speed
3. **3)** Barometric pressure
4. **4)** Relative humidity
5. **5)** Precipitation
6. **6)** Snow pack depth and extent

3.3.2B) Human activity measurements

1) Slope stability control activities
2) Dust control activities
3) Hazardous materials control activities
4) Trash control activities
5) Alien arthropod control activities

Sampling Intensities

3.3.2A all) As recorded by existing weather monitoring equipment.

3.3.2A6) Measure snow accumulations in Pu'u Hau Oki crater, should they occur. Measurement points every 120 feet horizontally along the upper edge of Pu'u Hau Oki crater and along the slope base at the bottom of Pu'u Hau Oki crater. Sampling target: 8 located measurement points. Map snow pack extent beyond Pu'u Hau Oki crater from aerial photographs, if available.

3.3.2B all) See Compliance Monitoring

Sampling Frequencies

3.3.2A all) As recorded by existing weather monitoring equipment.

3.3.2A6) Once per month, during periods when snow accumulates.

3.3.2B all) See Compliance Monitoring

Sampling Protocol:

3.3.2A all) See Protocols, Meteorological Station

3.3.2A6) **Tools:** Prepare measuring rods, using 12-foot-long fiberglass or metal fence posts, by painting white with red or black marks at one inch increments from top.
Procedures: Drive measuring rods securely into the slope every 120 feet on the contour, 10 feet slope distance below edge of construction areas for Outrigger Telescopes 1 & 2 (on the Pu'u Hau Oki crater side) and every 120 feet along the

slope base at the crater bottom (below the W.M. Keck site). Repair and restore (by raking) the slope surface around each measuring rod. Record the vertical distance (length in inches) from the surface to the top of each measuring rod. Subsequent measurements should be made using binoculars to view the rods from upslope and down slope positions (to minimize any further habitat disturbance). Repeat these measurements every month when snow pack is present.

3.3.2B all) See Compliance Monitoring

Data Management System: See Results, Data Management

Analysis and Interpretation Systems:

3.3.2A all) Time series analysis.

3.3.2A6) Spatial time series, dates and locations (depth and extent) of snow pack. Maps at dates (GIS).

3.3.2B all) Time series analysis.

Reporting System:

3.3.2A all) Include in Quarterly Reports, Construction Completion Report within two months after the completion of construction activities, and in the Post-Construction Report one year after completion of construction activities.

3.3.2B all) Include in Quarterly Reports, Construction Completion Report within two months after the completion of construction activities, and in the Post-Construction Report.

3.4 - HABITAT STRUCTURE MODULE

Question of Interest 3.4.1

3.4.1 How, where and when has existing Wēkiu bug habitat been damaged by new construction?

Justification:

Measurement of habitat damaged as a result of Outrigger Telescope construction is necessary to determine the appropriate amount of restoration needed for mitigation.

Monitoring goals:

1) To provide historical records of change in environmental phenomena, attributes, and characteristics.

Sampling Measurements

3.4.1A) Size and location of newly damaged Wēkiu bug habitat.

Sampling Intensities

3.4.1A) Locate perimeter points every 20 feet around the newly damaged areas. Locations should be accurate to ± 2 feet relative to fixed reference points, such as existing building corners or survey monuments. Sampling target: 15-20 located perimeter points, suitable for mapping the areas.

Sampling Frequencies

3.4.1A) Once after construction is complete.

Sampling Protocol: See Protocols, Wēkiu Bug Habitat

Data Management: See Results, Data Management

Analysis and Interpretation Systems:

3.4.1A all) Spatial time series, dates and locations, porosity profiles (cinder size distribution at depths below surface).

Reporting System:

3.4.1A all) Include in Construction Completion Report within two months after the completion of construction activities, and in the Post-Construction Report.

RESULTS

4.1 - DATA MANAGEMENT

The primary purpose of monitoring, as with any investigation, is to increase knowledge. Therefore the results, findings, and other forms of new information gained must be transmitted to decision-makers and stakeholders. The compilation, analysis, and presentation of results are key steps in the monitoring process.

Compilation of the findings is called data management. Much effort will be expended in the collection of raw data from field. That data must be checked for errors and archived for retrieval, as needed many years into the future.

Error checking is the first and most immediate task in data management. Field forms and types of raw data collected in this Monitoring Program will be examined for improper recording, blanks, or other errors. Error checking will be done daily during field collection sessions, at the end of the field day or that evening. If errors are found, they will be corrected immediately, or recollected the following day.

When appropriate, computerized error checking algorithms will be employed. Algorithms are useful for checking numerical data that conforms to known or expected distributions. For instance, weather data may be expected to fall into known ranges of temperature, wind speed, or precipitation. The error algorithm program will flag data values outside expected ranges. Investigators will be alerted, and the unusual data values can be verified or corrected through re-measurement or reentry into the database files. Utilization of error checking algorithms requires immediate entry into the computer, preferably on a daily basis.

Some types of data cannot be checked with algorithms. Records of dust suppression activities, snow plowing, barrier construction, and similar events must be "hand checked".

Data values will be entered into a set of database files. These will consist of prepared spreadsheets linked together for electronic queries. Data entry will be immediate, done daily during field collection sessions, at the end of the field day or that evening. Numerical data values may be recorded on hand-held or "palm" computers. Error checking algorithms may be included in the hand-held computer programs, thereby allowing error checking at the moment

of data entry in the field. Hand-held computer data will be downloaded into database files daily.

The database files will be backed up by storage in multiple computer data storage media and by hard copies.

The database files will contain all the field data. The files will be proprietary to the sponsors of the Monitoring Program. Data files will be released (shared) only with written permission of the sponsors. Released data files will always be accompanied by descriptions of the data collection methodology. Released data files may also be accompanied by analyses.

Some data will be spatial values indicating locations of events, activities, or phenomena. Spatial data will be stored in geographic information systems (GIS). GIS files may be shared with existing systems owned by IfA, UH, or other entities chosen by the sponsors.

4.2 - DATA ANALYSIS

Statistical analysis and scientific interpretation are necessary to produce logical inferences and new knowledge from monitoring data.

All data files will be initially evaluated using exploratory data analysis (EDA). EDA is a set of techniques for graphically examining data. Histograms, time series charts, multiple point plots, and other graphs aid in the visual examination of data. Visualization of data is a way of "decoding" quantitative and categorical information. Visual perception links numbers to understanding. Proper EDA includes display of mathematical (statistical) functions fit to the raw data. Simply graphing the data, without fitting and displaying the associated statistical models, may visually omit important traits of the data. Techniques employed will follow EDA guidelines elucidated by William S. Cleveland in his book "Visualizing Data", (Hobart Press, 1993).

Most of the data collected in monitoring is in the form of time series, a collection of observations made sequentially in time. The special characteristic of time series is that successive observations are not independent. Hence analyses of time series data must take into account the order of the observations. Non-independence means that future values are at least partially determined by past values. Because time series are deterministic, future values may often be predicted from past values, to some degree of accuracy. As a result, predictive models may be created for phenomena such as wildlife population changes.

There are many statistical methods for analyzing time series. The principal approach is the use of autocorrelation functions that quantify the deterministic links in processes through time. Frequency analysis, also called spectral analysis, is useful for analyzing the frequency of events. Survival analysis evaluates the time duration until an event occurs.

Time series often contain multiple patterns. The simplest pattern is trend, the increase or decrease of values over relatively long periods of time. Cycles may be detectable within trends, periodic fluctuations of values appearing over relatively shorter periods of time. Wildlife population changes often exhibit both long-term trends and short-term cycles.

Trends and cycles may best be evaluated using residual analysis. In residual analysis a trend model is fit to the data. The differences between the

actual values and the model values are known as the "residuals". Evaluating the model fit involves examination of the residuals for patterns. Once a good fit is established for the trend model, a cycle model may then be fit to the residuals. Again, the differences between the residuals and the cycle model are evaluated. These "second order" residuals are then examined for patterns. If the trend and cycle models are well fitted, the second order residuals should have no patterns; they should be small and random. This process often involves repeated (iterative) model fitting until the smallest and most random residuals result.

Wildlife population changes may be correlated with other phenomena, such as weather patterns, habitat changes, etc. The correlated phenomena are often also in the form of time series. Multivariate cross-correlation analyses are statistical methods for combining two or more time series. These methods are similar to the univariate methods described above, with the addition of cross-covariance terms in the models.

The ultimate purpose of time series analysis in monitoring is to develop models for predicting (and sometimes understanding) the changes. Prediction is simpler than understanding. Many phenomena that occur on a regular basis are highly predictable, even if we do not understand why they occur. For instance, the Monitoring Program may find that Wēkiu bug populations fluctuate with snowfall events or the lack thereof. Such fluctuations may be predictable, even if we do not understand the biological mechanisms at work.

Other statistical methods may also be employed. Mark-and-recapture techniques may be useful in making population estimates. In mark-and-recapture of insects, non-toxic phosphorescent dyes are carefully placed on captured bugs, which are then released. The percentage of marked individuals subsequently recaptured yields potentially more accurate inferences about the size of the population than simple trap counts.

Spatial analyses, using statistical methods for evaluating location data, may also be useful. It is unlikely, however, that the projected sampling intensities will reveal detectable patterns in the locations of Wēkiu bug population changes. To detect such changes many times more traps would be necessary. In this Monitoring Plan we have chosen to minimize habitat damage by data collectors and focus on population changes detectable with the fewest traps, and hence the least habitat disturbance.

4.3 - REPORTING

The new knowledge acquired through monitoring will be communicated to sponsors and stakeholders through reports. Five types of reports are anticipated:

1. Reviews. This Monitoring Plan calls for reviews of habitat restoration plans; soil-binding compounds to be applied, and hazardous material spill response plans, among others. These reviews will be done on a timely basis, so that construction activities are not delayed.

2. Quarterly Reports. Results from monitoring will be reported every three months during construction of the Outrigger Telescope. Progress on compliance, including restoration of habitat, installation of barriers, dust suppression activities, trash control activities, etc., will be conveyed in the Quarterly Reports.

3. Construction Completion Report. Within two months after completion of construction activities a comprehensive report will be issued. This report will address all the Questions of Interest, and provide a historical record of compliance with guidelines and the effectiveness of mitigation activities.

4. Post-Construction Report. Eighteen months after completion of habitat restoration activities a second comprehensive report will be issued. This report will address primarily the Effectiveness Monitoring QOI's; including any Wēkiu bug population changes detected.

5. Immediate Reports. If any special problems or events happen during or after construction, those situations will be reported immediately. Such occurrences as hazardous material spills, excessive side cast of cinder or trash into Wēkiu bug habitat, or establishment of colonies of alien arthropods at the Keck site, will be reported upon detection to the proper authorities, (selected by the Monitoring Program sponsors).

All the reports will be clearly written for use by the intended audience: JPL, NASA, CARA, IfA, UH, DLNR, and other stakeholder groups and individuals. The reports will include charts, tables, maps, photographs and other visual displays of the information acquired through monitoring.

As the Monitoring Program progresses, feedback from stakeholders will be used to improve the reports to enhance understanding of the results. Future decision-making may then be based on clear, reliable, new information about the Wēkiu bug and the effects of mitigation activities.

SCHEDULE

The schedule for monitoring is dependent upon start of the Outrigger Telescopes Project and is still to be determined. The schedule in this section is generic and representative of the actual time. The dates are undetermined and are dependent upon permitting for the Outriggers Telescope Project.

Updates to this schedule can be found on the World Wide Web at:

http://www.statpros.com/Wekiu_Bug.html

MONITORING SCHEDULE		CONSTRUCTION MONITORING MONTHS																				
		CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10	CM11	CM12	CM13	CM14	CM15	CM16	CM17	CM18	CM19	CM20	CM21
Phases		2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a	2a
		2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b	2b
Compliance Monitoring																						
Module	**QOI**																					
2.3 Habitat Restoration	1	A,B																B,C				
2.4 Slope Stability	1	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B
	2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	3								A	A	A	A	A								A	A
	4																	A				
2.5 Dust	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	4	A,B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
2.6 Hazardous Materials	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	2	A,B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	3	A,B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
2.7 Trash	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2.8 Alien Arthropods	1	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	2	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B
	3	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	4	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
	5	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B
Effectiveness Monitoring																						
Module																						
3.3 Population	1	A,B			A,B			A,B			A,B			A,B			A,B			A,B		
	2	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B
3.4 Habitat	1																	A				

				POST CONSTRUCTION MONITORING MONTHS																	
CM22	CM23	CM24	CM25	PCM1	PCM2	PCM3	PCM4	PCM5	PCM6	PCM7	PCM8	PCM9	PCM10	PCM11	PCM12	PCM13	PCM14	PCM15	PCM16	PCM17	PCM18	
2a	2a	2a	2a	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
2b	2b	2b	2b																			
																						QOI
			C																		C	1
A,B	A,B	A,B	A,B																			1
A	A	A																			A	2
A	A	A								A	A	A	A	A								3
			A																			4
A	A	A																				1
A	A	A																				2
A	A	A																				3
B	B	B																				4
A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	1
B	B	B																				2
B	B	B																				3
A	A	A																				1
A	A	A																				2
A	A	A																				3
A	A	A																				4
A	A	A																				1
A,B	A,B	A,B																				2
A	A	A																				3
A	A	A																				4
A,B	A,B	A,B																				5
A,B			A,B			A,B			A,B			A,B			A,B			A,B			A,B	1
A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	A,B	2
			A																			1

PROTOCOLS

Protocols for the sampling systems are included in the Compliance and Effectiveness Monitoring sections above. Some protocols are too complicated to be included in those sections and are given in this section. Protocols included in this section include, Wēkiu Bug Population Sampling, Wēkiu Bug Habitat Sampling, Contractor's Log Books, Meteorological Data Gathering, Alien Arthropod Inspections, and Compliance Visual Inspections.

6.1 - WEKIU BUG POPULATION PROTOCOL

Population estimates are classified into three types, relative estimates, absolute estimates, and population indices. Relative estimation is based on the catch per unit effort and is the most appropriate method for monitoring Wēkiu bug population change. Absolute estimates are collected by sampling known fractions of the habitat. This technique would be destructive of habitat, and is therefore inappropriate for Wēkiu bug population monitoring. Population indices are derived from measurements of animal products (e.g. frass, webs, nests) or effects (plant damage) and are not applicable to Wēkiu bugs.

Nondestructive sampling is the best approach to monitoring rare and sensitive invertebrate species. Data on relative abundance can be collected with specially designed live traps that cause minimal disturbance to Wēkiu bugs or their habitats.

Monitoring during Outrigger construction and operation will involve capturing Wēkiu bugs in improved live-traps similar to those used in the 1997-98 MKSR arthropod assessment. These traps provide Wēkiu bugs with food, moisture, and protection from predators and can sustain captured individuals for several days. Traps will be checked for Wēkiu bugs every three days during the sampling session. Captured bugs will be counted, marked with non-toxic, luminous powder, and released. The number of recaptured marked bugs will provide additional information about population change.

Materials

10 oz clear plastic drinking cups
12 oz clear plastic drinking cups
¼" mesh hardware cloth (12.5" square)
coffee filters
dried shrimp
luminous powder (various colors)
gum Arabic
mortar and pestle
trowel

30 foot ladder
½" rebar (18" lengths)
¼" nylon rope
small sledge hammer
dark-cup illuminator
dusting bulb insufflator

Luminous Dust

Fluorescent substances, whose presence can be detected by placing the marked animals under an UV light, have been used extensively by entomologists in capture-recapture studies. The markers are considered safe for most insects, although some species are sensitive, and experience decreased longevity when exposed to some fluorescent substances.

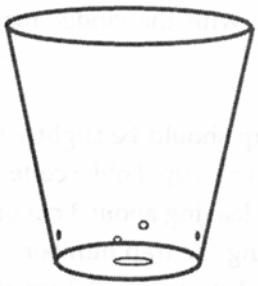
Specially formulated luminous powders are available from entomology equipment suppliers, and are considered the safest insect marking substance. They may be applied directly, but better adhesion is obtained when the dusts are combined with gum arabic. Mix one part luminous dust with six parts gum arabic until a paste is formed. Allow the paste to dry for at least 3 days. Pulverize the dry mixture to dust in a mortar. Store the dust mixture in sealed vials until needed. Apply dust with a dust bulb insufflator.

Traps

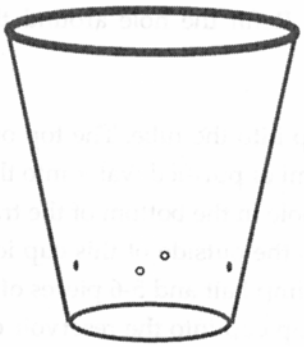
Construction

1. Remove the rim of the 10 oz cup and cut a hole 1.5 cm diameter hole in the bottom.
2. Punch four 2 mm holes around the side of the 10 oz cup about 1 cm from the bottom. Punch four 2 mm holes around the side of the 12 oz cup about 4 cm from the bottom.
3. Connect opposite edges of the hardware cloth making a wire tube the 12 oz cup will fit into.

4. Fold a coffee filter 5 times and insert into the hole at the bottom of the 10 oz cup, leaving about 3 cm sticking up into the cup.



10 oz cup
Trap Cup



12 oz cup
Reservoir Cup

wire tube

Location

Traps in Wēkiu bug habitat will be installed at permanent monitoring stations and capped when not in use. Thirteen permanent stations will be established, five in Pu'u Hau Oki, five in Pu'u Wēkiu, and three in newly restored habitat.

Installation

Extend the ladder to its full open position on the crater floor. The bottom of the ladder should just touch the cinder slope below the sampling station. Drive an 18" length of rebar into the substrate on each side of the bottom of the ladder. Attach the bottom of the ladder to the rebar using nylon rope. Tie a 50 foot length of rope to the top rung of the ladder. Stand the ladder upright. Holding onto the rope attached to the top, gently lower the ladder onto the slope. Drive an 18" length of rebar into the substrate on

each side of the top of the ladder. Attach the top of the ladder to the rebar using nylon rope. Repeat for each sampling station.

Install a trap at each sampling station (at the top of the ladders) by carefully digging into the cinder, disturbing only the amount of cinder necessary to set up the trap. Place the hardware cloth tube into the hole so that the top of the tube is slightly below the existing surface. Refill the hole around the tube with the cinder that was removed from the hole.

Place the reservoir cup into the tube. The top of the cup should be slightly below the cinder surface. Pour 15 ml of purified water into the reservoir cup. Fold a coffee filter 5 times and insert into the hole in the bottom of the trap cup, leaving about 3 cm of filter in the cup. Attach a label to the outside of this cup identifying the trap number. Add 3 pieces of pre-moistened shrimp bait and 5-6 pieces of local substrate (i.e., 2-3 cm cinder) to the trap cup. Place the trap cup into the reservoir cup such that the coffee-filter wick makes contact with the water reservoir.

Distribute chum, consisting of pureed pre-moistened shrimp, around the trap and place the trap cover such that the entire trap is shaded from sunlight. Attach a flag to the trap cover. Record on data sheet the trap number, date set, time set, and distance to nearest snow patch.

Collection

Remove the cap rock and remove the trap-cup from the trap. Carefully inspect the cinder in the cup, and record the number of Wēkiu bugs and presence of other arthropods in the trap.

Gently place captured Wēkiu bugs into the dark-cup illuminator and inspect each Wēkiu bug for luminous powder. Record the number of individuals with luminous dust and the colors of the dust if any is found. Dust all captured bugs with luminous powder using the dust bulb insufflator. Record the number of bugs marked and the dust color on the data sheet.

Release all live specimens at least one meter away from the sampling station. Wēkiu bugs should not be handled or exposed to direct sunlight for more than 30-45 seconds. Observe released bugs for one minute, making sure they find cover.

At the end of the sampling session remove the reservoir cup and replace the cap rock and flag. Remove the ladders from the crater.

6.2 - WEKIU BUG HABITAT PROTOCOL

Monitoring during Outrigger construction and operation will include sampling Wēkiu bug habitat to measure the locations and extents of restored habitat and habitat mitigation structures. In addition, the cinder structure in restored and mitigated habitat will be measured and monitored for changes.

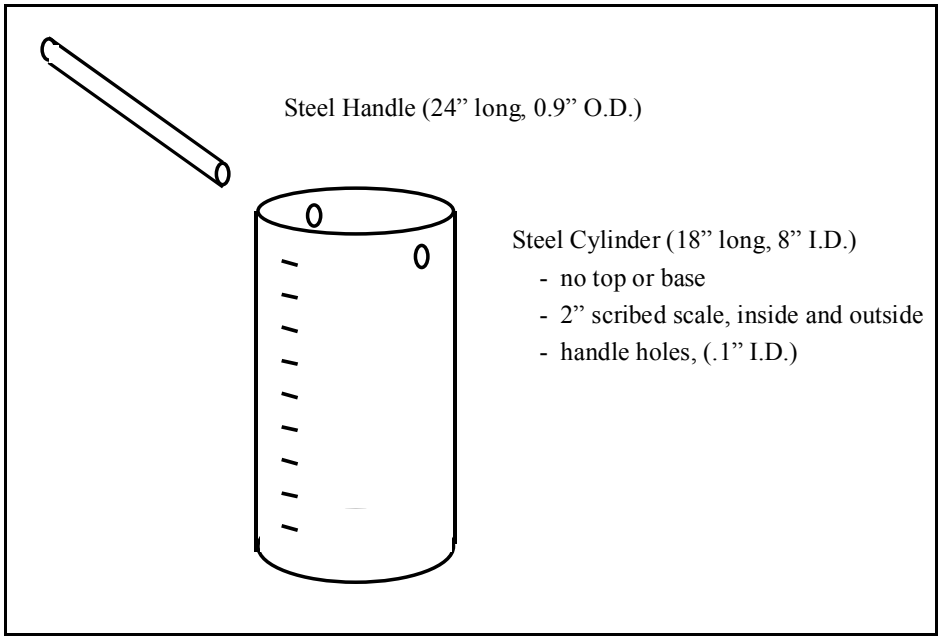
Researchers have determined that Wēkiu bugs live in the interstitial spaces, or voids, between the rocks in the surface layer. In the alpine environment of Mauna Kea's summit ice, frost heaving, and snowmelt wash and stratify the surface layer of cinder in the summit cones. Progressively larger rocks are lifted to the surface and washed clean of ash, which in turn accumulates in a layer 12 to 18 inches below the surface. This process is thought to create the interstitial spaces in which Wēkiu bugs live. The surface layer in restored habitat areas will be monitored for changes in interstitial porosity.

Materials

1 cylindrical shovel (see next section)
1 small trowel
~ 100 lidded containers (1/2 gallon)
100′ tape
3 screens (1″, 1/2″, 1/8″ meshes) ~ 12″x12″
scale
graduated cylinder or beaker (1 liter)

Cylindrical Shovel

The cylindrical shovel is a steel tube 8 inches in diameter and 18 inches long. The shovel has a drive handle and scribing that allows the operator to determine the depth the shovel is driven.



Locating Sampling Points

Thirteen sampling points in Wēkiu bug habitat will be installed at temporary monitoring stations: five in Puʻu Hau Oki, five in Puʻu Wēkiu, and three in newly restored habitat or habitat mitigation structures. These points will be established at trapping locations (see Population Protocol). This protocol will be implemented at those points prior to trap installation.

Additional sampling points in Wēkiu bug habitat will be necessary to monitor habitat structure changes over time, (any and all sampling point locations may be used only once). Additional points will be located using a grid established with a random starting point and random azimuth.

1) Place a grid map over a map of the site.
2) Randomly select one point on the grip as a starting point, (use a random number generator to select *x* and *y* coordinates).
3) Randomly select an azimuth, (use a random number generator to select a number between 0 and 360).
4) Re-orient the grid map, pivoting on the randomly chosen starting point, aligning the grid lines with the randomly chosen azimuth.
5) Sampling points may then be located at the re-oriented grid line intersections.

Field Collection

Drive the cylindrical shovel, perpendicular to the surface, as deep as possible. Carefully extract the cinder from within the cylinder in two-inch depth increments. Place each two-inch layer in a separate container for lab analysis. Mark each container with the sampling point number and the depth increment, (such as, Point 4 Hau Oki, 6-8 inches below surface). If necessary, drive the shovel deeper after extracting the top layers, so that 18" of cinder is eventually cored and removed. Following extraction of 9 two-inch layers, remove the shovel and fill the hole with loose cinder from the immediate vicinity.

Lab Analysis

For each two-inch layer sample, separate cinder particles by size using the three screens. Four fractions will be thus created. Submerge each fraction in a graduated beaker containing a known volume of water, and record the volume displacement, (i.e. the volume of the fraction). A wetting agent may be used in the water to eliminate small air bubbles that may cling to the cinder particles.

Calculate the particle size distribution of each two-inch layer (volume by particle-size-class). Calculate the porosity of each two-inch layer, (1 minus the ratio of the combined volume of the fractions to the total field volume of the layer). Note that each layer had a total field volume of $2\pi 4^2 = 100.5$ cubic inches.

6.3 - CONTRACTORS' LOG BOOK PROTOCOL

INSTRUCTIONS FOR FORM 1 - TRUCKS, EQUIPMENT, MATERIALS

The function of Form 1, Contractors' Log Book, is to provide a record of all trucks, heavy equipment, and construction materials that are transported to the Mauna Kea summit during construction of the Outrigger telescopes.

The purpose is to monitor for possible introductions of alien arthropods into Wēkiu bug habitat. Efforts to prevent alien arthropods from reaching the summit will help insure that the Wēkiu bug population is protected.

Information about each truck that arrives at the summit should be recorded in one column of Form 1, (one column per truck). The following numbered instructions correspond to the numbered rows on Form 1.

1: Arrival Time & Date

The **Arrival Time** is the hour, plus AM or PM, when each truck arrives at the construction site. The **Date** is the month, day, and year of arrival. Write down the hour of day and the date, (mm/dd/yy), when a truck arrives at the site.

2: Departure Time & Date

The **Departure Time** is the hour, plus AM or PM, when the truck leaves the construction site. The **Date** is the month, day, and year of departure. Write down the hour of day and the date, (mm/dd/yy), when the truck leaves the site. **One column per truck** means that the truck departing must be the same truck whose arrival is noted in the blank space above in the same column.

TRUCKS

3: Truck ID

The best **Identification Number** of a truck is its license plate number. Write down the license plate number of each truck that visits the construction site.

4: Number of Axles

Write down the number of axles, including those on any trailers attached to the truck.

5: Contents

Write down the contents of the load carried by the truck when it arrives at the construction site. **Contents** may be such things as: water, heavy equipment, construction materials, etc.

6: Loading location

Write down the address where the contents were loaded onto the truck. Include the **Name**, **Street Address,** and **City.**

7: Truck Owner

Write down the name of the person or company who owns the truck.

8: Truck Storage Yard

Write down the address where the truck (and trailer if applicable) is(are) stored when not in use. Include the **Street Address** and **City.**

9: Excess Mud on Truck?

Walk completely around the truck (and trailer if applicable) and note the presence of mud, dirt, or vegetation. In particular, inspect the undercarriage, axles, and wheel wells. Write down **YES** if the truck has clumps of mud or dirt larger than your fist, or if vegetation is clinging to the undercarriage. Write down **NO** if excess mud, dirt, or vegetation are not present on the truck (and trailer if applicable).

HEAVY EQUIPMENT

10: Heavy Equipment ID

Write down the **License Plate or Vehicle Identification Number** of each piece of heavy equipment arriving at the construction site**.** It is expected that heavy equipment will arrive on trucks Therefore, the information on each piece of heavy equipment should go in the same column as the information on the truck that transported it.

11: Type

Write down the **Type** of heavy equipment this piece is**.** Types of heavy equipment may be such things as loader, grader/scraper, back hoe, bulldozer, ditcher/excavator, fork lift, crane, snow plow, etc.

12: HE Owner

Write down the name of the person or company who owns this piece of heavy equipment**.**

13: HE Storage Yard Location

Write down the address where this piece of heavy equipment is stored when not in use. Include the **Street Address** and **City.**

14: Excess Mud on HE

Walk completely around this piece of heavy equipment and note the presence of mud, dirt, or vegetation. In particular, inspect the undercarriage, axles, wheel wells, tracks, and attachments. Write down **YES** if the heavy equipment has clumps of mud or dirt larger than your fist, or if vegetation is clinging to the undercarriage. Write down **NO** if mud, dirt, or vegetation are not present on the heavy equipment.

MATERIALS

15: Type of Materials

If the contents of the truck are construction materials, then write down the **Type** of materials arriving at the construction site. Types of materials may be such things as lumber and plywood, reinforcement bar (re-bar), concrete, steel beams and girders, building blocks, paints and/or solvents, etc.

16: Quantity

Write down the quantity of the construction materials on the truck. Also, be sure to specify the units, (gallons, pallets, cubic yards, etc.).

17: Evidence of Arthropods?

Examine the materials for signs of arthropods. Write down **YES** if there are signs of arthropods on the arriving materials. Write down **NO** if signs of arthropods are not present. Signs of arthropods include:

a. Ants, spiders, or other insects crawling on the materials
b. Spider webs on or among the materials
c. Small piles of sand-grain sized particles (frass) on wood objects
d. Clumps of mud or dirt
e. Clumps of vegetation

WEKIU BUG MONITORING PLAN - CONTRACTORS' LOG BOOK

FORM 1 - TRUCKS, EQUIPMENT, MATERIALS

Instruction Note No.		Example		
1	Arrival Time & Date	10 AM, 6/21/01		
2	Departure Time & Date	4 PM, 6/22/01		
	TRUCKS			
3	Truck ID	Lic: ABC123		
4	Number of axles	3		
5	Contents	Water		
6	Loading location	Co. Water Dept., XXXX Kaumana Dr., Hilo		
7	Truck Owner	A-1 Trucking		
8	Truck storage yard	XXXX Hinano St., Hilo		
9	Excess mud on Truck?	No		
	HEAVY EQUIPMENT			
10	Heavy Equipment ID			
11	Heavy Equipment Type			
12	Heavy Equipment Owner			
13	HE storage yard location			
14	Excess mud on HE?			
	MATERIALS			
15	Type	Water		
16	Quantity	1,000 gals		
17	Evidence of arthropods?	No		

WEKIU BUG MONITORING PLAN - CONTRACTORS' LOG BOOK

FORM 1 - TRUCKS, EQUIPMENT, MATERIALS

Instruction
Note No.

1	Arrival Time & Date			
2	Departure Time & Date			
	TRUCKS			
3	Truck ID			
4	Number of axles			
5	Contents			
6	Loading location	o		
7	Truck Owner			
8	Truck storage yard			
9	Excess mud on Truck?			
	HEAVY EQUIPMENT			
10	Heavy Equipment ID			
11	Heavy Equipment Type			
12	Heavy Equipment Owner			
13	HE storage yard location			
14	Excess mud on HE?			
	MATERIALS			
15	Type			
16	Quantity			
17	Evidence of arthropods?			

INSTRUCTIONS FOR FORM 2 - DUST, TRASH, HAZARDOUS MATERIALS

The function of Form 2, Contractors' Log Book, is to provide a record of all efforts to control dust, trash, and hazardous materials during construction of the Outrigger telescopes.

The purpose is to monitor for possible impacts to Wēkiu bug habitat. Recording control efforts will help insure that Wēkiu bug habitat is protected.

Information about daily control efforts should be recorded in one column of Form 2, (one column per day). The following numbered instructions correspond to the numbered rows on Form 2.

1: Date

Write down the **Date** of the log entry, month/day/year. Use one column per day, unless you require more room to record numerous control activities taking place on the same day . In that case, use a second or third column as needed, but be sure to clearly mark the **Date** in each column, (mm/dd/yy).

DUST CONTROL

2: Substrate type

The **Substrate Type** means the surface or substance to which dust control measures are be applied. Write down the substrate type where the dust-generating activity occurred. Common substrate types are: excavation (hole), cinder stock pile, road, parking lot, staging area, screened cinder, etc.

3: Location

Write down the location of the dust-generating activity. When excavations are for foundations and footings, specify the number of the nearest Outrigger (1 – 4). When excavations are for light tunnels, specify the origin and destination of the light tunnel. Write down the number of the nearest Outrigger (1 – 4) or staging area designation for cinder piles and construction pads.

4: Water applied? Quantity?

Write down **YES** if water was applied to the substrate to control dust. Write down **NO** if no water was used during the dust generating activity. Also write down the approximate quantity of water (in gallons) applied to the substrate.

5: Soil binders used? Type? Quantity?

Soil binders are chemicals that hold soil and dust particles together and prevent dust from being dispersed into the air. Soil binders may be mixed with water and applied to the substrate to control dust. Write down **YES** if soil binders were applied to the substrate, or **NO** if soil binders were not applied to the substrate. Write down the **Type or Brand Name** of the soil binder. Types of soil binders may be manufactured substances, soybean oilsoapstock, or lignins. Brands of manufactured substances include Soil-Sement, Pennzsuppress, and others. Record the Brand from the container. Report the **Quantity** of soil binder used, before mixing with water, and the units. **Reminder**: no soil binding compounds should be applied to cinder that will be used for habitat restoration.

6: Suspended for high winds?

Write down **YES** if any construction activity was suspended because of wind. Write down **NO** if no construction activities were suspended due to winds.

7: Covered? Type?

Some substrate, such as excavations or cinder stock piles, may be covered to prevent wind-generated dust. Write down **YES** if a substrate was covered, or **NO**, if the substrate was not covered. Also write down the **Type** of cover used. Cover types include tarps, plywood, etc.

TRASH

8: Roll-off containers covered?

Roll-off containers are large containers that are left at the site to receive waste materials. Write down **YES** if roll-off containers are securely covered to prevent wind-blown trash Write down **NO** if roll-off containers are not covered. Write down **NONE** if there are no roll-off containers on site on this day.

9: Construction materials covered?

Construction materials may be covered or tied down to prevent them from being blown off the site by high winds. Write down **YES** if construction materials were covered or anchored on this day. Write down **NO** if construction materials were not covered or anchored on this day.

10: Wind-blown debris?

Wind-blown debris may be trash, construction materials, or other items blown beyond the construction site boundaries. Write down **YES** if any debris was blown or fell beyond the construction site boundaries on this day. Write down **NO** if no debris was blown or fell beyond the construction site boundaries on this day.

11: If yes to 10, types, quantities.

If you wrote YES to No. 10, describe the types of debris and the quantities blown beyond the construction site boundaries on this day. **Types** of wind-blown debris include such things as plywood, plastic sheeting, packing material, paper, sheet metal, or other material. Estimate the size and number of the items.

HAZARDOUS MATERIALS

12: Chemicals used on site?

Chemicals are manufactured substances that are used during construction and maintenance of the Outriggers and the Observatory. These include paints, thinners, solvents, fuels, cleaners, acids, and mirror-coating materials. Write down **YES** if chemicals were used at the site on this day. Write down **NO** if chemicals were not used at the site on this day.

13: Types, quantities.

Write down the **Types** of chemicals (noted in No. 12) that were used at the site on this day. Write down the quantities of the chemicals used. Quantities may be a count of the number of containers (specify capacity), or the volume or weight of the chemicals used on this day. Be sure to specify the units.

14: Spills?

Spills are defined as any quantity of a chemical coming in contact with a surface or substrate to which it was not intended to be applied. Write down **YES** if a spill occurred on this day. Write down **NO** if no spill occurred on this day.

15: If yes to 14, to whom reported?

Spills should be reported to:

_____, ph _____ or to

_____, ph_____ .

Write down the name of the person to whom the spill was reported, and their phone number.

WEKIU BUG MONITORING PLAN - CONTRACTORS' LOG BOOK

FORM 2 - DUST, TRASH, HAZARDOUS MATERIALS

Instruction Note No.		Example		
1	Date	6/21/01		
	DUST CONTROL			
2	Substrate type	Excavation		
3	Location	O1 to JB4		
4	Water applied?, Quantity?	Yes, 250 gal		
5	Soil binders used? Type?, Qty?	Yes, SoilSement, 1qt.		
6	Suspended for high winds?	No		
7	Covered?, Type?	Yes, tarp		
	TRASH			
8	Roll-off containers covered?	Yes		
9	Construction materials covered?	Yes		
10	Wind-blown debris?	No		
11	If yes to 10, types, quantities	None		
	HAZARDOUS MATERIALS			
12	Chemicals used on site?	Yes		
13	Types, quantities	water-base paint, 5 gal		
14	Spills?	No		
15	If yes to 14, to whom reported	None		

WEKIU BUG MONITORING PLAN - CONTRACTORS' LOG BOOK

FORM 2 - DUST, TRASH, HAZARDOUS MATERIALS

Instruction Note No.				
1	Date			
	DUST CONTROL			
2	Substrate type			
3	Location			
4	Water applied?, Quantity?			
5	Soil binders used? Type?, Qty?			
6	Suspended for high winds?			
7	Covered?, Type?			
	TRASH			
8	Roll-off containers covered?			
9	Construction materials covered?			
10	Wind-blown debris?			
11	If yes to 10, types, quantities			
	HAZARDOUS MATERIALS			
12	Chemicals used on site?			
13	Types, quantities			
14	Spills?			
15	If yes to 14, to whom reported			

6.4 - METEOROLOGICAL STATION PROTOCOL

Monitoring weather during Outrigger construction and operation will include frequent sampling of temperature, humidity, windspeed, and precipitation. Wēkiu bugs are found only in the extreme alpine environment of Mauna Kea's summit. Extreme weather phenomena are thought to be associated with Wēkiu bug population change. Monitoring weather will provide measured variables to include in population change analyses. In addition, wind speed monitoring will provide data for determination of daily mitigation actions, such as dust control.

Several of the observatories have weather stations, and the information is readily available over the internet. Using existing weather stations will save costs and disturbance to habitat from installation of new equipment.

Tools

Computer with internet access.

Procedures

Access weather data at Mauna Kea Weather Center web site at http://hokukea.soest.hawaii.edu/index.html . Download weather information from UKIRT data logger. .

Download digital data monthly.

6.5 - ALIEN ARTHROPOD INSPECTION PROTOCOL

Arthropods that do not occur naturally at the summit area have the potential to disturb Wēkiu bug populations. Predators like ants and spiders are especially threatening. Regular inspections called for in the monitoring plan are intended to detect alien species so that they may be eradicated before being transported to the construction site.

This protocol is designed to be implemented by non-technical personnel and should detect most viable alien arthropod colonies present. Solitary arthropods are unlikely to establish populations at the summit and represent only a small threat to Wēkiu bugs.

Tools magnifying glass, knife, trowel. Notebook.

Targets soil, mud, vegetation, ants, spiders and spider webs, egg masses, frass, and yellowjacket nests.

Procedures

1. Construction materials Walk slowly around construction materials, trash containers, and shipping crates and examine all sides for ants, spiders, spider webs, egg masses, frass, and yellowjacket nests.

2. Vehicles Examine all of the wheel wells, wheels, tires, treads, and undercarriages of earth-moving equipment, large trucks, tractors, and other heavy equipment. Examine for ants, spiders, spider webs, egg masses, and yellowjacket nests. Also examine for soil, mud, dirt, vegetation, and other debris attached.

3. Buildings Examine sides of each building or structure, from base to 10 feet above the ground. Examine for ants, spiders, spider webs, egg masses, and yellowjacket nests.

Reporting

Type Describe what was inspected (e.g. construction material, vehicle, equipment, building)

Location Describe the general location of the subject inspected relative to fixed reference points.

Findings Describe the types and numbers of arthropods detected (e.g. ants, spiders, etc.), the types of arthropod artifacts detected (e.g. spider webs, yellowjacket nests, frass, etc.), and/or the type of arthropod habitats detected (e.g. soil, mud, vegetation, etc.).

6.6 - COMPLIANCE VISUAL INSPECTION PROTOCOL

Compliance monitoring investigates whether programs and personnel are following the guidelines established for protection of the Wēkiu bug. Random site inspections averaging one per month will be conducted during Outrigger construction to ensure compliance with the guidelines. The results of the random site inspections will be included in the quarterly reports

Tools

100' tape measure, compass, notebook

Procedures

1. Note the locations of temporary barriers and verify their installation near excavations and other earth-moving activities (see QOI 2.4.1). Inspect and record the condition of the barriers (e.g. holding side-cast cinder, failing, etc.). Verify compliance with Wēkiu Bug Mitigation Plan Recommendation IV-3. Temporary, and if possible, permanent barriers should be built along the slope breaks above the inner slopes of Pu'u Hau Oki crater. Report non-compliance or barrier failures to the construction-site manager.

2. Visually inspect for side-cast material (see QOI 2.4.2). Verify compliance with Wēkiu Bug Mitigation Plan Recommendation IV-3. Under no circumstances should cinder or other materials be side-cast into Wēkiu bug habitat. Report side-cast cinder to the construction-site manager.

3. Visually inspect active earth-moving operations, excavated materials and cinder stock piles (see QOI 2.5.1, QOI 2.5.2, & QOI 2.5.3). Verify compliance with Wēkiu Bug Mitigation Plan Recommendation V-1. Water should be applied to excavation sites and cinder stockpiles. Verify Contractors' Log Book entries regarding Dust Control (CLB Form 2, Lines 2-7). Verify compliance with Wēkiu Bug Mitigation Plan Recommendation V-2. Dust-generating activities should be suspended and construction materials secured during high winds, and water should be applied to

recently exposed cinder and ash. Report non-compliance to the construction-site manager.

4. Visually inspect applications of soil-binding compounds (see QOI 2.5.4). Verify compliance with Wēkiu Bug Mitigation Plan Recommendation V-3. Soil-binding amendments should be used sparingly, and should never be applied to Wēkiu bug habitat. Verify Contractors' Log Book entries regarding Dust Control (CLB Form 2, Line 5). Report non-compliance to the construction-site manager.

5. Locate and observe the use of paints, thinners, and solvents and cleanup procedures. Describe cleanup and disposal activities (see QOI 2.6.2 and QOI 2.6.3). Describe spills, if any. Verify compliance with Wēkiu Bug Mitigation Plan Recommendation VI-2. Contractors should minimize the on-site use of paints, thinners, and solvents. Painting and construction equipment should not be cleaned on-site. Contractors should keep a log of hazardous materials brought on-site and report spills to a designated WMKO representative. Verify Contractors' Log Book entries regarding Hazardous Materials (CLB Form 2, Lines 12-15).Report non-compliance to the construction-site manager.

6. Visually inspect construction trash containers (see QOI 2.7.1). Describe trash containers, covers, and anchoring devices. Verify compliance with Wēkiu Bug Mitigation Plan Recommendation VII-1. Construction trash containers should be tightly covered to prevent construction wastes from being dispersed by wind. Verify Contractors' Log Book entries regarding Trash (CLB Form 2, Lines 8-11). Report non-compliance to the construction-site manager.

7. Visually inspect construction materials stored at the site (see QOI 2.7.2 and QOI 2.8.3). Describe material, covers, and anchoring devices. Verify compliance with Wēkiu Bug Mitigation Plan Recommendation VII-2. Construction materials stored at the site should be covered with tarps, or anchored in place, and not be susceptible to movement by wind. Verify Contractors' Log Book entries regarding Dust Control (CLB Form 2, Line 9). Walk slowly around the materials and examine for ants, spiders, spider webs, and yellowjacket nests. Report uncovered or unanchored material, or alien arthropods to the construction-site manager.

8. Locate and describe outdoor trash receptacles, and their lids and anchors (see QOI 2.7.3). Verify compliance with Wēkiu Bug Mitigation Plan Recommendation VII-3. Outdoor trash receptacles should be secured to the ground and have attached lids. Report non-compliance to the construction-site manager.

9. Locate and describe construction materials, trash, and wind-blown debris in Wēkiu bug habitat (see QOI 2.7.4). Describe the debris, general location, and retrieval activities if any. Verify compliance with Wēkiu Bug Mitigation Plan Recommendation VII-4. If construction materials and trash are blown into Wēkiu bug habitat, they should be collected without disturbing the habitat. Verify Contractors' Log Book entries regarding Trash (CLB Form 2, Lines 10-11). Report non-compliance to the construction-site manager.

10. Locate all large trucks, tractors, and other heavy equipment (see QOI 2.8.2 and QOI 2.8.3). Record vehicle identification numbers. Verify Contractors' Log Book entries regarding Trucks (CLB Form 1, Lines 1-14).Verify compliance with Wēkiu Bug Mitigation Plan Recommendation VIII-1. Earthmoving equipment should be free of large deposits of soil, dirt and vegetation debris that could harbor alien arthropods. Walk slowly around each vehicle and examine all of the wheel wells, wheels, tires, treads, and undercarriages. Examine and record the presence of spiders, spider webs, egg masses, ants, and other arthropods. Also examine and record the presence of soil, mud, dirt, vegetation, and other debris attached. Describe the presence of arthropods or arthropod harboring debris if any are found. Report alien arthropod presence to the construction-site manager.

11. Locate shipping crates and boxes. Examine and record the presence of spiders, spider webs, egg masses, ants, and other arthropods(see QOI 2.8.4). Also examine and record the presence of soil, mud, dirt, vegetation, and other debris attached. Describe the presence of arthropods or arthropod harboring debris if any are found. Verify Contractors' Log Book entries regarding Materials (CLB Form 1, Lines 15-17). Report alien arthropod presence to the construction-site manager.

12. Locate portable buildings and toilet facilities. Walk slowly around these structures and examine for ants, spiders, spider webs, or yellowjacket nests (see QOI 2.8.5). Record the presence of alien arthropods and describe their general location and the

degree of infestation. Report alien arthropod presence to the construction-site manager.

13. Walk slowly around the observatory building and outriggers, and examine for ants, spiders, spider webs, or yellowjacket nests (see QOI 2.8.5). Record the presence of alien arthropods, and describe their general location and the degree of infestation. Report alien arthropod presence to the construction-site manager.

APPENDIX F

Construction Best Management Practices Plan (BMP)

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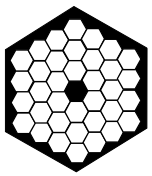
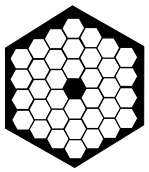


W. M. KECK OBSERVATORY
CALIFORNIA ASSOCIATION FOR RESEARCH IN ASTRONOMY



Keck Interferometer Outrigger Telescopes

CONSTRUCTION BEST MANAGEMENT PRACTICES PLAN (BMP)

Draft Revision A

January 23, 2002

Keck Interferometer Plan

Title:	**Construction Best Management Plan (BMP)**
Author:	James Bell (CARA)
Version:	A – Draft pending site works contract
Date:	1/23/2002
Approvals:	Jim Beletic
Cc:	Peter Wizinowich (CARA), Jim Kelley (JPL)

Upon obtaining project approval for the new Keck Outrigger Telescopes, this Best Management Practices Plan (BMP) will be used to guide all activities associated with construction of the outrigger telescopes. The plan will serve as a working document that may be expanded and revised prior to project start. It will become part of the agreements/contracts with site work contractors. The purpose of this document is to facilitate project management by developing an organizational structure that will guide construction management, designate who has the authority to make decisions, and provide a checklist to ensure compliance with all mitigating measures and conditions on the project. It is a primary management tool for the CARA Construction Manager and Contractor's Project Manager. This Best Management Practices Plan becomes null and void if for some reason the project fails to move forward.

I. OVERVIEW

A. PURPOSE

The purpose of the Construction Best Management Practices Plan (BMP) is to specify the methods and controls which will be implemented to prevent or minimize negative impacts to the surrounding environment, and to the natural and cultural resources on and adjacent to the W. M. Keck Observatory (WMKO) site during the construction of the Outrigger Telescopes project. Included in these controls is a proposed organizational structure which clearly sets forth the lines of authority and responsibility that will ensure proper supervision and oversight throughout the construction process.

The BMP will be overseen by the CARA Construction Manager and implemented by the Contractor's Project Manager. A Construction Management Organization Chart, identifying the proposed hierarchy and working relationships among the various interested parties, is attached (Figure 1). The BMP and accompanying organization chart will be finalized by CARA in coordination with the selected Contractor. It will also be attached to the construction contracts. The CARA Construction Manager will have the primary responsibility for all construction activities.

B. SCOPE OF THE CONSTRUCTION BMP

All construction activities related to the Outrigger Telescopes Project—from delivery of materials and equipment (to either the WMKO site or one of the two construction staging areas, Figure 2), through final clean up of the staging areas, stockpile area (Figure 3) and WMKO site—will be controlled by the BMP. These activities include, but are not limited to:

- Unloading containers at the staging area and delivering the contents to the site.
- Installing sheet piling, as required by the Hawaii Electric Light Company (HELCO), to protect power cables from inadvertent disturbance by construction equipment. Removal of piles upon completion of construction will also adhere to this plan.
- Excavating and trenching for junction boxes, light pipes and air pipes, enclosure and telescope footings, underground coudé rooms and tunnels.
- Removing excess excavated material, not used for backfill, to the approved summit stockpile area (Figure 3) to be screened, washed and used for Wēkiu habitat restoration on and adjacent to WMKO site.
- Grading and shoring for Outrigger Telescope enclosures and junction boxes, including placement of fill and construction of retaining walls.
- Pouring concrete (ready-mixed in Hilo or Waimea) for a tunnel, ring wall, retaining walls and telescope foundations.
- Installing up to five prefabricated junction boxes and up to six prefabricated coudé rooms (or pouring concrete if prefabricated structures are unavailable).
- Installing light pipes (together with electrical conduits) and air pipes.
- Assembling prefabricated enclosures, consisting of ring walls and rotating domes, on site; setting the ring walls on concrete footings and installing the domes on their tops.
- Installing a telescope, dual star module and other hardware within each enclosure.
- Complying with the Wēkiu Bug Mitigation Plan, including the restoration of Wekiu bug habitat.

- Maintaining the summit construction staging and stockpile areas (Figure 3), on-site stockpile areas and the construction staging area at Hale Pohaku (Figure 2) in clean, safe condition.
- Care and maintenance of equipment and vehicles.
- Cleanup of all construction areas.
- Complying with the Memorandum of Agreement on cultural resources.

II. ENVIRONMENTAL AND CULTURAL CONCERNS

A. WĒKIU BUG

Although the actual construction site has been altered by past development activities, nearby Wēkiu bug habitat could be affected by construction of the proposed project (Figure 4). The major negative effects that could occur during Outrigger Telescope construction are: trash, dust, side-cast cinder, introduction of non-native species, and spills of hazardous materials. The control and mitigation of these concerns will follow the Wēkiu Bug Mitigation Plan. Foot traffic in Wēkiu Bug habitat can be harmful to the habitat. The Construction Manager will ensure that the only foot traffic in the habitat will be with the concurrence of the project entomologist.

B. CULTURAL CONCERNS

Historic District. The State Historic Preservation Division (SHPD) believes that the summit region of Mauna Kea is eligible for listing in the National Register of Historic Places as an Historic District. The cluster of cones forming the summit, including Puʻu Hauʻoki, would be a contributing historic property to this district and itself meets the criteria for listing in the National Register of Historic Places. Measures that would prevent or minimize activities that would further impact the structural and visual integrity (i.e., shape and contour) of the Puʻu Hauʻoki cinder cone and its crater are a primary focus of the BMP.

Potential Burial Sites. Most of the land to be used for the Outrigger Telescopes has been previously altered to such an extent that there is a low probability of discovering burials on the site. An exception to this applies to areas near the outer edges of the Puʻu Hauʻoki plateau, where it had not been previously disturbed other than being subjected to side-casting of cinder from the original grading of the plateau. Because the existence of burials cannot be conclusively verified, the project archeologist will monitor all excavation.

View Planes. All above ground parts of junction boxes and retaining walls will be colored to match the cinder.

III. PRE-CONSTRUCTION ACTIONS

A. COORDINATION

Prior to construction mobilization, meetings will be held to finalize all aspects of the construction process. The following information will be exchanged between CARA (including the Archeological, Cultural and Wēkiu Bug Monitors) and the Contractor at least two weeks before these meetings take place.

1.0 Information to be provided by CARA

a) A location map identifying all construction, staging and stockpile areas.

b) A description of the type, composition and quantity of material expected to be excavated during the project and its disposition.

c) A description of the type, composition and quantity of fill material to be used, including locations of temporary on-site stockpiles.

d) A chart showing preferred construction sequence (a schedule of construction activities) that will: (a) minimize potential adverse cultural and environmental effects, and (b) allow efficient scheduling of appropriate monitoring times.

e) A Construction Management Organization Chart, such as shown in Figure 1, that will clearly delineate lines of authority and responsibility; phone numbers of key personnel will also be included.

f) Provide a detailed description of specific mitigating measures to protect and preserve the natural and historic/cultural attributes of the project area.

g) Based on the Organization Chart, designation of areas of responsibility, names and phone numbers of responsible individuals, names and phone numbers of special advisors, and steps that will be taken to accomplish the following:
   - control of all trash and construction material stored on site;
   - removal of all trash on a regular basis;
   - monitoring of construction activity to ensure that no cinder or other materials are side-cast into the Puʻu Hauʻoki crater or the outer slopes of the cone;
   - ensuring compliance with all provisions of the Section 106 memorandum of agreement (MOA) to be entered into by NASA, the Advisory Council on Historic Preservation, State Historic Preservation Officer, and others;
   - monitoring the on-site use of paints, thinners, and solvents and other hazardous materials and reporting spills to designated individuals;
   - ensuring that earth-moving equipment is free of large deposits of soil, dirt and vegetation debris that may harbor non-native species; and
   - ensuring that new non native species introductions detected during monitoring as described in Wēkiu Bug Monitoring Plan are eradicated;
   - ensuring compliance with all provisions of the Wēkiu Bug Mitigation Plan.

h) A list of telephone numbers of the responsible persons and alternates to be contacted (day or night) when violations are suspected. (After inspecting a particular incident, these individuals report their findings to the CARA Construction Manager; they do not interact with the workers or try to fix it themselves except for the archaeologist has the immediate authority to stop construction work in the area of an identified or potential find. The resource or burial could easily be destroyed by the time the Construction Manager is found, the issue discussed, and directive given. The archaeologist may also be responsible for discussing any findings with the SHPO and the cultural monitor under the Section 106 MOA.

i) A set of criteria to be used when determining whether or not to stop construction.

j) An emergency response plan for unplanned events to be based on the CARA Safety Manual.

2.0 Information to be provided by the Contractor

a) A list identifying the characteristics of raw materials to be brought to the site or lay down area, including:
   - the type of materials to be used, by construction phase;

- the frequency of delivery of these materials to the site;
- the quantities to be stored and length of storage;
- the location of proposed on-site storage and stockpile areas; and
- a description of how the Contractor would clean and care for these areas and materials.

b) A written summary of the characteristics and source of any discharge and potential pollutants associated with each construction activity together with proposed control measures or treatment methods, including but not limited to the following discharges:
   - solid waste,
   - oily waste,
   - hazardous waste, and
   - equipment cleaning and washing of cement truck mixers.

c) A written summary describing the type and characteristics of vehicles and equipment to be used, including:
   - the duration of use by construction phase by vehicle and equipment type;
   - emission characteristics by vehicle and equipment type;
   - noise characteristics by vehicle and equipment type;
   - type of fuel used by vehicle and equipment type; and
   - on-site use and/or storage area(s) for each type of equipment.

d) An implementation plan for suspending all dust-generating activities and securing equipment and materials during high winds and storms.

e) A plan to control wind and water erosion during the construction period.

f) An implementation plan for cleaning vehicles and equipment to rid them of non-native species of plants and animals prior to transportation to the construction site.

B. ARCHAEOLOGICAL CONSULTATION

CARA and the Contractor will meet at least 2 weeks before construction starts with a qualified archaeologist as defined in the MOA (known as the project archeologist) to determine the scope and schedule of archaeological monitoring activities during the construction period. The archaeologist will first identify potentially sensitive construction areas on the WMKO site. The archaeologist, in coordination with the CARA Construction Manager and the Contractor, will develop standards and criteria for monitoring excavation activities and determining when remedial actions are required and work must be stopped. The archaeologist will then be present on site to monitor all excavation. The archaeologist will follow SHPD standards for archaeological monitoring studies and reports (HAR Chapter 279). The archaeologist has the immediate authority to stop construction work in the area of an identified or potential find. The archaeologist may also be responsible for discussing any findings with the SHPO and the cultural monitor under the Section 106 MOA. The archeologist is encouraged to work with the cultural monitor in developing monitoring plans and actual monitoring. The archeologist has the discretion to make random visits to the project site, but for safety reasons must check in with the Construction Manger before entering the site.

C. CULTURAL MONITORING

The CARA Construction Manager and the Contractor will meet with the project cultural monitor to determine the scope and schedule of cultural monitoring activities during the construction period at least 2 weeks before construction starts. The cultural monitor, in coordination with the CARA Construction Manager and the Contractor, will develop standards and criteria for monitoring construction activity and determining when remedial actions are required. Details of the monitoring and required qualifications of the monitor are defined in the cultural resources MOA. The project cultural monitor is encouraged to work with the project archeological monitor in developing monitoring plans and actual monitoring. The project cultural monitor has the discretion to make random visits to the project site, but for safety reasons must check in with the Construction Manger before entering the site.

D. FINALIZE PLANS AND PROCEDURES

The CARA Construction Manager and the Contractor Project Manager will meet, discuss and revise all information and produce a final Organization Chart, a set of criteria for ensuring compliance with all mitigating measures, and criteria and procedures for stopping construction if necessary.

E. PREPARE MONITORING AND REPORTING SCHEDULES

The CARA Construction Manager, in consultation with various specialists and the Contractor, will prepare schedules for monitoring on-going activities for compliance with the BMP. Procedures for reporting violations and the status of corrective measures to bring the project into compliance will also be determined. The name and phone number of each monitor will be identified.

F. FIELD MANUAL OF PROCEDURES AND PRACTICES

The CARA Construction Manager, in cooperation with CARA, the Contractor, OMKM and special advisors, will prepare a manual which will incorporate the finalized BMP; specific emergency response plans for injuries, medical emergencies, and fire; other standard practices (CARA's safety manual); and protocols for Wēkiu bug and cultural mitigation. Both CARA and the General Contractor will approve this manual.

The CARA Construction Manager will schedule mutually agreed upon meetings with the Archaeologist, Cultural Monitor, and OMKM, to ensure that work is being carried out according to applicable terms of the MOA.

G. EDUCATION

Prior to starting work on the project site, all project personnel and all contractor(s) employees will be briefed on and shown a videotape concerning the cultural significance of the project area. OMKM will be consulted on the production of the video and advised on the briefings. A natural resource specialist will brief them on the importance of protecting the Wēkiu habitat. Mitigating measures for both cultural and natural resources will be explained in detail. They will also be advised of procedures that must be taken in the event of an infraction of the conditions imposed on the project. Suggestions as to the most effective ways of informing their workers about the importance of adhering to all of the stipulations set forth in the agreement will also be discussed. The archaeological monitor and the cultural monitor will also give presentations to project personnel and contractor employees as specified in the MOA.

IV. CONTROLS

A. CONSTRUCTION SAFETY ZONES

1.0 Pu'u Hau Oki Crater Rim and Outer Slopes

Temporary 3-foot-high silt fences will be installed along the rim of the Puʻu Hauʻoki crater and outer slopes, where excavation or trenching is planned to take place where any significant potential that material may be overcast down slope. At a minimum the fences will be located down slope of any area to be excavated within 6 feet of the slope. The temporary silt fences will be maintained by the contractor on a daily basis to repair any damage.

2.0 Other Construction Areas

a) Construction safety fencing and temporary signage to deter unauthorized visitors and Observatory personnel from inadvertently entering into construction zones will delineate each area under construction. To the extent possible, the color of the fencing will blend in with the surrounding cinder terrain.

b) As the construction in each area is completed, the fencing and signage will be removed as soon as practicable.

c) The fencing and signage will remain at any area where archaeological artifacts are found until the State Historic Preservation Division approves removal, if any, of the fencing and temporary signage.

B. HEALTH AND SAFETY

1.0 Noise

a) The Contractor will minimize high noise levels from construction equipment by outfitting all equipment with proper noise muffling devices.

b) The Contractor will comply with State Department of Health (DOH) rules (HAR, Chapter 46, Community Noise Control).

2.0 Air Quality

The Contractor will comply with Hawaii DOH rules (HAR Chapter 11, Section 60.1, Air Pollution Control) and the County of Hawaii grading permit as well as this BMP.

a) Dust Control

- fugitive dust will be minimized by spraying with potable water or other environmentally acceptable suppressant as necessary. The Wekiu Bug Monitor will define what is environmentally safe; and
- all dust-generating activities will be suspended during high winds. The critical velocity of these winds will be determined later but is assumed to be about 40 to 50 miles per hour (64 to 80 kilometers per hour).
- Cinder stored in the summit stockpile area at the project site will be covered with heavy tarps as needed to minimize dust.

b) Emissions

- all engine emissions will be mitigated by the use of properly functioning emission control devices as required by law;
- all construction equipment will be properly maintained;
- equipment idling will be kept to a minimum when equipment is not in use.

3.0 Worker Safety

All personnel working on the project site including monitors must attend Pre-Start Safety Induction training that will cover at a minimum:

- CARA and Contractor Safety Policy
- Contractor MSDS Management and Control
- Discussion of harards associated with working at high alititude
- Review of lockout proceedure on dome and telescope.
- Reporting accidents
- Emergancy medical treatment for workers in the event of an accident
- Dealing safely with hazardous materials
- Highlight the critical proceedures that are most likely to affect workers or the project.

The Contractor will comply with all OSHA standards and regulations.

C. WASTE CONTROLS

The Contractor will comply with all Hawaii DOH rules.

Every member of the construction crew, managers, observatory personnel, and other people associated with the proposed Outrigger Telescopes Project will undergo an orientation about the impacts of the Outrigger Telescope construction and installation, and how they may prevent and minimize disturbance caused by trash.

1.0 Solid Waste (Construction and Domestic)

a) Construction materials and supplies will be prevented from being blown into Wēkiu bug habitat and historic properties by covering them with heavy canvas tarps, using steel cables attached to anchors.

b) Construction trash containers will be tightly covered to prevent construction wastes from being dispersed by wind.

c) Outdoor trash receptacles will be secured to the ground and have secured lids and plastic liners.

d) "Roll off" containers will be equipped with heavy canvas tarps held securely with cables. Containers will be collected on a regular basis before they are completely full or overflowing.

e) All trash will be removed to an authorized disposal site in either Hilo or Waikoloa. This will be done on at least a weekly basis throughout the construction period.

f) As necessary, a magnetic device will be driven over roadways to remove metallic debris.

2.0 Toxic/Hazardous Waste

a) Contractors will minimize the on-site use of paints, thinners, and solvents.
b) Painting and construction equipment will not be cleaned on-site.
c) Contractors will keep a log of toxic/hazardous materials, if any, brought on-site and their disposition.
d) Spills will be immediately reported to the CARA Construction Manager who will activate the appropriate emergency response procedures.
e) Any toxic/hazardous waste generated by the construction project will be properly disposed of as recommended by CARA's Hazardous Disposal consultant.

D. ACCIDENTIAL CHEMICAL RELEASES

1.0 Precautions

a) Fuel tanks of equipment and construction vehicles will not be filled to the top.
b) Equipment will be properly secured during non-working hours, away from previously identified (during pre-construction activities) sensitive areas.
c) Fuel spill clean-up kits will be readily accessible at the work area at all times.

2.0 Spill Response Plan

a) Procedures for spill response are included in CARA's Safety Manual. Additional requirements will be added if necessary.
b) The Contractor will comply with all Federal and State DOH rules and regulations.

E. SPECIAL CONCERNS

1.0 Cultural Resources

a) Any human remains discovered during the construction process will immediately be reported to the CARA Construction Manager. As set forth in HAR 13-300-40, "Inadvertent discovery of human remains," the Archeologist will immediately order all work stopped in the area of the discovery and report the findings to the following:
   - the State Historic Preservation Division, unless the discovery occurs on Saturday, Sunday or holiday, at which time the report shall be made to the Division of Conservation and Resources Enforcement;
   - the University of Hawaii Office of Mauna Kea Management;
   - the Hawaii County medical examiner or coroner; and
   - the Hawaii County Police Department.

   Work in the discovery area can resume only upon approval of SHPD.
b) Because use of the construction staging and/or stockpile areas within the summit area of the Science Reserve may affect the landscape of a proposed historic property (the summit area of Mauna Kea), the following precautions must be observed:
   - construction materials stored at the site must be anchored in place and not be susceptible to movement by wind;
   - trash must not be scattered over the site; and

- trash containers must be secured to the ground and tightly covered to prevent construction wastes from being dispersed by wind.

c) The construction staging and stockpile areas on the summit (and in some instances at Hale Pohaku) must be inspected for compliance with the BMP every evening (after the work day is completed), and during high winds and storms. The construction staging and stockpile areas must also be inspected upon completion of all construction and habitat restoration activities to ensure that the areas have been restored.

d) All stipulations in the cultural resource MOA related to construction activities, as well as conditions attached to the Conservation District Use Permit, will be incorporated into this BMP and the construction contract.

2.0 Wēkiu Bug

a) Non-native species

- monitoring will be undertaken to identify any no-native species infestations at the Outrigger Telescopes construction site and staging areas;
- large deposits of soil, dirt and vegetation debris that may harbor non-native species will be removed from all earth-moving equipment by pressure washing or other means at the Contractor's base yard before ascending Mauna Kea;
- large trucks, tractors, and other heavy equipment will be inspected for non-native species at the Contractor's base yard or marine terminal and at the intersection of the Saddle Road and the Summit Road; the inspection near the intersection of the Saddle and Summit Roads will be conducted by a qualified biologist. If non-native species are found at the intersection of the Saddle and Summit Roads, the qualified biologist can either remove the non-native species or send the vehicle back to the base yard for required cleaning;
- the Contractor will ensure that all construction materials, crates, shipping containers, packaging material, and observatory equipment are free of non-native species when delivered to the summit; and
- new non-native species introductions detected during monitoring of the Outrigger Telescopes construction site and staging areas including, but not limited to, ants, yellow jackets and alien spiders, shall be eradicated.

b) Wēkiu Bug Habitat Protection

- soil-binding amendments will be used sparingly
- if construction materials and trash are blown into Wēkiu bug habitat (Figure 4), it will be collected by staff trained by the project entomologist taking care to minimize habitat disturbance.

c) Wēkiu Bug Habitat Restoration. Excess excavated material, not used for backfill or site grading, will be removed to the approved stockpile area, screened and washed. The cinder will be sieved for ½" and larger size and washed with an estimated 1 gal/ft^3. The sieving and washing process should be done simultaneously to minimize a dust plume. All material of suitable size will be used to restore Wēkiu bug habitat on or adjacent to Puʻu Hauʻoki. Any remaining material will be placed in the summit area after consultation with the SHPD and Office of Mauna Kea Management.

- The project entomologist will be on site during the habitat restoration and will have the necessary authority to ensure that the work is done properly;
- new cinder will be placed only on previously-disturbed surfaces;
- to the extent possible, the new cinder will match the existing cinder;
- washing of the cinder will be done in such a way that there is no erosion or other marking of the landscape by runoff;
- screening and washing of cinder will occur in an up-slope section of the staging area that is farthest removed from unaltered ground surfaces down slope.

3.0 Construction Staging Areas

a) The Hale Pohaku and summit construction staging areas will be inspected each evening to ensure that all materials are secured and that all trash is placed in appropriate approved containers.

b) When in use, the staging areas will be checked daily for oil spills from vehicles. These spills will be cleaned up immediately and the offending vehicle(s) will be removed from the mountain for maintenance.

c) The staging areas will be checked regularly for the presence of non-native species; any infestations will be immediately eradicated.

4.0 Potential Interference with Observatories

a) Use of exterior lighting is not permitted between sunset and sunrise.

b) Use of any radio transmitter that may interfere with observatory operations is not permitted.

5.0 Photographic Record

a) The contractor shall keep a photographic record of all construction activities on the site starting with pictures before any activities, during and after. This record shall be available for viewing in the site project office. At the end of the job the contractor will deliver 2 copies of the photos, one for CARA and another for OMKM.

V. ENFORCEMENT

It is the responsibility of the CARA Construction Manager to enforce the provisions of the BMP. All monitors will report their findings to him or her.

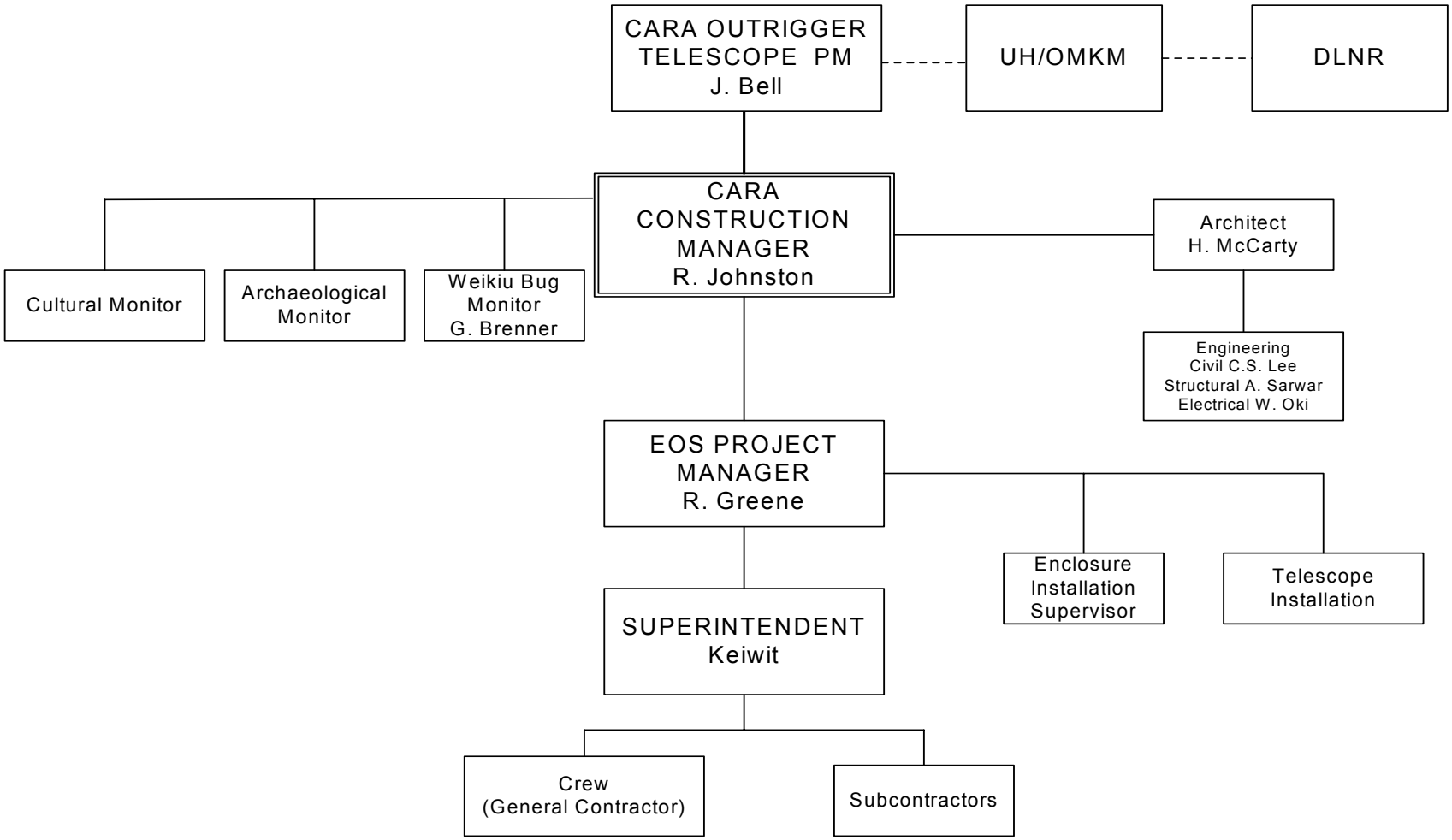


Figure 1
CONSTRUCTION MANAGEMENT ORGANIZATION CHART

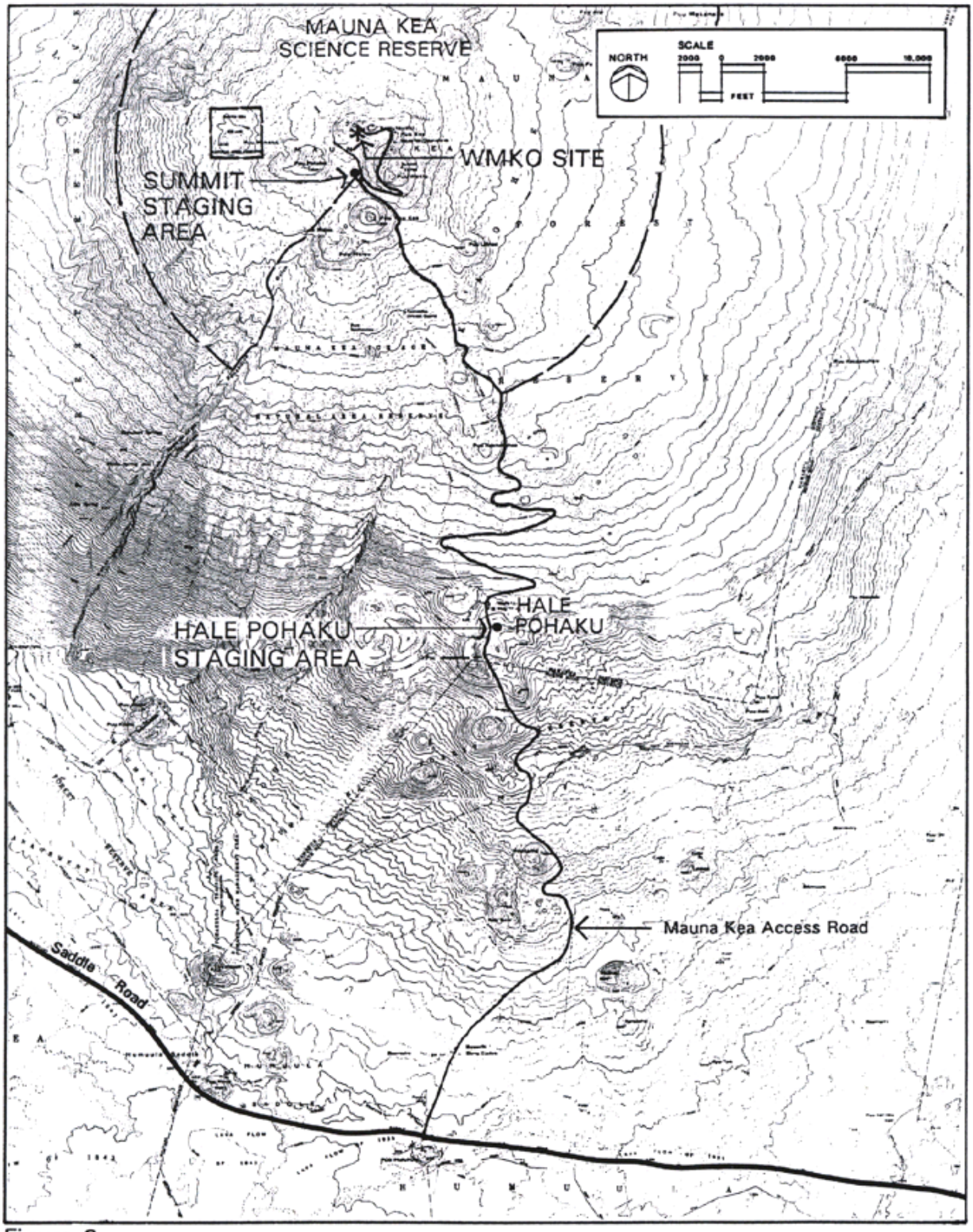


Figure 2
CONSTRUCTION STAGING AREAS

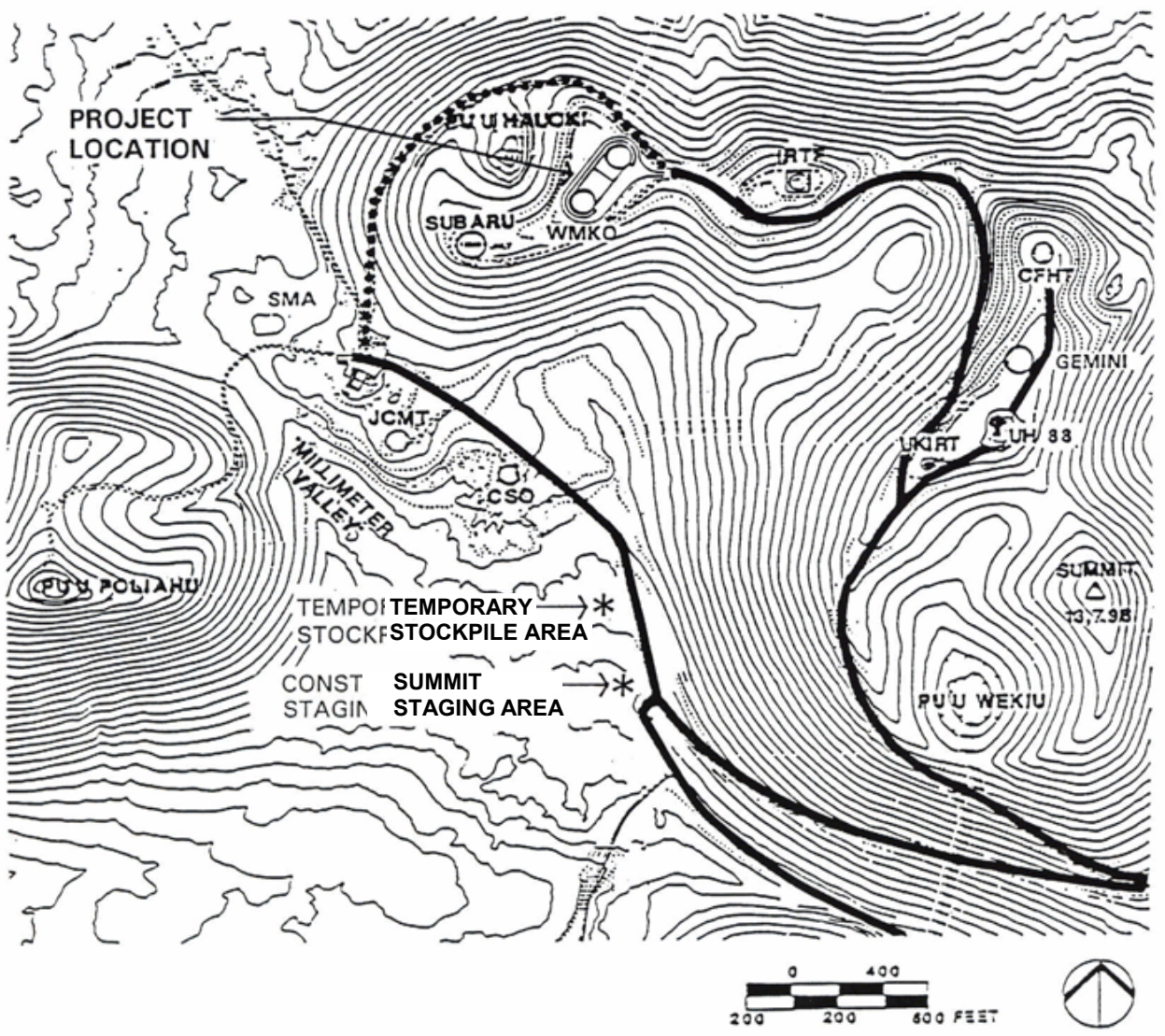
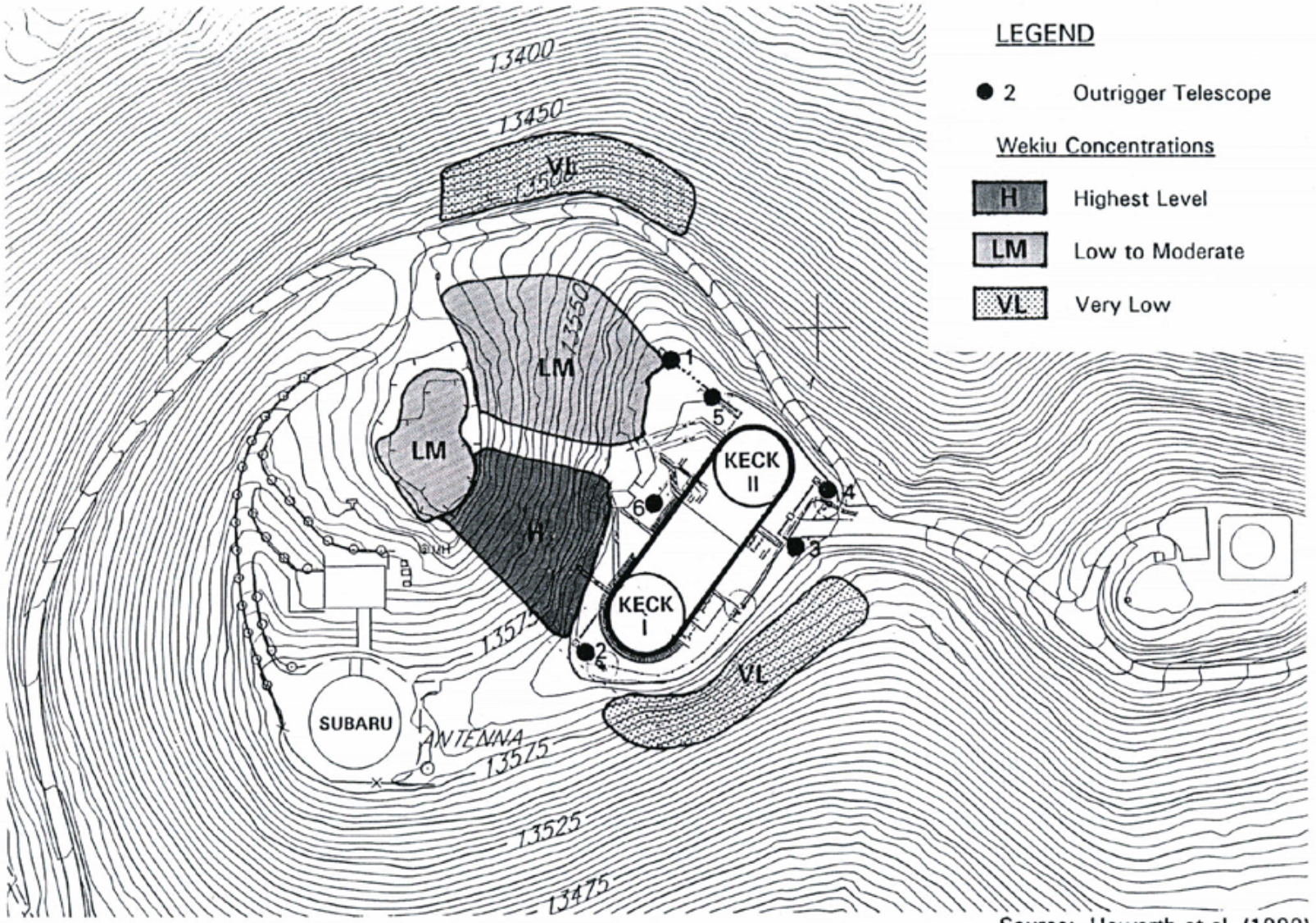


Figure 3
LOCATION OF THE PROJECT WITHIN THE SUMMIT AREA



Source: Howarth et al. (1999)

Figure 4

PU'U HAU OKI: AREAS OF WEKIU BUG CONCENTRATION (1997-1998)